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SCIENTIFIC DIALOGUES,

INTENDED FOR THE

INSTRUCTION AND ENTERTAINMENT

OF

YOUNG PEOPLE:

IN WHICH

THE FIRST PRINCIPLES

OF

NATURAL AND EXPERIMENTAL PHILOSOPHY

ARE FULLY EXPLAINED.

VOL. VI. OF ELECTRICITY AND GALVANISM.

"Conversation, with the habit of explaining the meaning of words, "and the structure of common domestic implements to children, is the "sure and effectual method of preparing the mind for the acquirement of "science." EDGEWORTH'S PRACTICAL EDUCATION.

BY THE REV. J. JOYCE.

A NEW EDITION, CORRECTED AND IMPROVED.

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CONTENTS

TO

VOL. VI.

ELECTRICITY.

Conversation		Page
I.	Early History of Electricity..	1
II.	Electrical Attraction and Repulsion.....	9
III.	Electrical Machine.....	21
IV.	Electrical Machine.....	32
V.	Electrical Attraction and Repulsion.....	43
VI.	Electrical Attraction and Repulsion.....	58
VII.	The Leyden Phial.....	65
VIII.	Lane's Electrometer, and the Electrical Battery:.....	78
IX.	Experiments with the Battery..... ..	89
X.	Miscellaneous Experiments.....	103
XI.	Electrophorus, Thunder-house, &c.....	114
XII.	Atmospherical Electricity.....	122
XIII.	Aurora Borealis: Water-Spouts; Earthquakes.....	134
XIV.	Medical Electricity.....	152
XV.	Animal Electricity.....	160
XVI.	Summary of Electricity.....	169

GALVANISM, OR VOLTAISM.

Conversation Page

I. The Origin of Galvanism.... 180

II. Galvanic Light and Shocks..... 190

III. Voltaic Conductors, Circles, Tables, &c. 200

IV. Miscellaneous Experiments..... 216

V. Glossary and Index..... 227

CONVERSATION I.

INTRODUCTION.

The early History of Electricity.

TUTOR. If I rub pretty briskly with my hand this stick of sealing-wax, and then hold it near any small light substances, as little pieces of paper, the wax will attract them; that is, if the wax be held within an inch or less of the paper, they will jump up, and adhere to it.

Charles. They do; and I think I have heard you call this the effects

of electricity, but I do not know what electricity is.

Tutor. It is the case with this part of science as with many others, we know it only by the effects which it produces. As I have not hitherto, in these Conversations, attempted to bewilder your minds with useless theories, neither shall I, in the present case, attempt to say what the electrical fluid is: its action is well known; it seems diffused over every portion of matter with which we are acquainted, and, by the use of proper methods, it is as easily collected from surrounding bodies as water is taken from a river.

James. I see no fluid attaching to the sealing-wax when you have rubbed it.

Tutor. You do not see the air which you breathe, and with which

you are surrounded, yet we have shown you* that it is a fluid, and may be taken from any vessel, as certainly, though not with so much ease, as water may be poured from this glass. With the exercise of a small degree of patience, you shall see such experiments as will not fail to convince you, that there is as certainly a fluid, which is called the electric fluid, as there are such fluids as water and air.

Charles. Water must have been known since the creation, and the existence of the air could not long remain a secret, but who discovered the electric fluid, which is not at all evident to the sense either of sight or feeling?

Tutor. Thales, who lived six cen-

* See Vol. IV.

turies before the Christian æra, was the first who observed the electrical properties of amber, and he was so struck with the appearances, that he supposed it to be animated:—

Bright *amber* shines on his electric throne,
And adds ethereal lustre to his own.

DARWIN.

James. Does amber attract light bodies, like sealing-wax?

Tutor. Yes, it does; and there are many other substances, as well as these, that have the same power. After Thales, the first person we read of that noticed this subject was Theophrastus, who discovered that *tourmalin* has the power of attracting light bodies. It does not, however, appear that the subject, though very curious, excited much attention till about 200 years ago, when Dr. Gil-

bert, an English physician, examined a great variety of substances, with the view of ascertaining how far they might or might not be ranked among *electrics.*

Charles. What is meant by an *electric?*

Tutor. Any substance, which being excited or rubbed by the hand, or by a woollen cloth, or other means, and which has the power of attracting light bodies, is called an *electric.*

James. Is not electricity accompanied with a peculiar kind of light, and with sparks?

Tutor. It is, of which we shall speak more at large hereafter: the celebrated Mr. Boyle is supposed to have been one of the first persons who got a glimpse of the electrical light, or who seems to have noticed

it, by rubbing a diamond in the dark. But he little imagined, at that time, what astonishing effects would afterwards be produced by the same power. Sir Isaac Newton was the first who observed, that excited glass attracted light bodies on the side opposite to that on which it was rubbed.

Charles. How did he make the discovery?

Tutor. Having laid upon the table a round piece of glass, about two inches broad, in a brass ring, by which it was raised from the table about the eighth of an inch, and then rubbing the glass, some little bits of paper which were under it were attracted by it, and moved very nimbly to and from the glass.

Charles. I remember standing by

a glazier when he was cementing, that is, rubbing over some window-lights with oil, and cleaning it off with a stiff brush and whiting, and the little pieces of whiting, under the glass, kept continually leaping up and down, as the brush moved over the glass.

Tutor. That was, undoubtedly, an electrical appearance of the same kind, but I do not remember having ever seen it noticed by any writer on electricity. A complete history of this science is given by Dr. Priestley, which will, hereafter, afford you much entertainment and interesting instruction. To morrow we shall enter into the practical part of the subject: and I doubt not, that the experiments in this part of science will be as interesting as those in any other

which you have been studying. The electric light, exhibited in different forms; the various signs of attraction and repulsion acting on all bodies; the electric shock, and the explosion of the battery, will give you pleasure, and excite your admiration.

The peculiar phenomena, which attend electrical attraction and repulsion, are highly deserving of attentive consideration; for upon them the subject of electricity depends. Though their effects are striking, and though they have been exhibited under an endless variety of forms, yet the true cause upon which they depend is not yet fully understood.

CONVERSATION II.

Of Electric Attraction and Repulsion —Of Electrics and Conductors.

TUTOR. You must, for a little time, that is, till we exhibit before you experiments to prove it, take it for granted, that the earth, and all bodies with which we are acquainted, contain a certain quantity of exceedingly elastic and penetrating fluid, which philosophers call the electric fluid.

Charles. You say a certain quantity: is it limited?

Tutor. Like other bodies, it undoubtedly has its limits; this glass will hold a certain quantity of water, but, if I attempt to pour into it more than that quantity, a part will flow over. So it is with the electric fluid: there is a certain quantity which belongs to all bodies, and this is called their natural quantity, and so long as a body contains neither more nor less than this quantity no sensible effect is produced.

James. Has this table electricity in it?

Tutor. Yes, and so has the inkstand, and every thing else in the room; and, if I were to take proper means to put more into it than it now has, and you were to put your knuckle to it, it would throw it out in the shape of sparks.

James. I should like to see this done.

Charles. But what would happen if you should take away some of its natural quantity?

Tutor. Why then, if you presented any part of your body to the table, as your knuckle, a spark would go from you to the table.

James. But perhaps Charles might not have more than his natural share, and, in that case, he could not spare any.

Tutor. True; but to provide for this, the earth on which he stands would lend him a little, to make up for what he parted with to the table.

James. This must be an amusing study; I think I shall like it better than any of the others.

Tutor. Take care that you do not

pay for the amusement before we have done.

Here is a glass tube about eighteen inches long, and perhaps an inch or more in diameter; I rub it up and down quickly in my hand, which is dry and warm, and now I will present it to these fragments of paper, thread, and gold-leaf: you see they all move to it. That is called electical *attraction.*

Charles. They jump back again now; and now they return to the glass.

Tutor. They are, in fact, alternately attracted and repelled, and this will last several minutes, if the glass be strongly excited. I will rub it again: present your knuckle to it in several parts one after another.

James. What is that snapping? I feel, likewise, something like the pricking of a pin.

Tutor. The snapping is occasioned by little sparks which come from the tube to your knuckle, and these give the sensation of pain.

Let us go into a dark room, and repeat the experiment.

Charles. The sparks are evident enough now, but I do not know where they can come from.

Tutor. The air, and every thing, is full of the fluid, which appears in the shape of sparks; and, whatever be the cause, which I do not attempt to explain, the rubbing of the glass with the hand collects it from the air, and, having now more than its natural share, it parts with it to

you, or to me, or to any body else that may be near enough to receive it.

James. Will any other substance besides the hand, excite the tube?

Tutor. Yes, many others, and these, in this science, are called the *rubbers;* and the glass tube, or whatever is capable of being thus excited, is called an *electric*.

Charles. Are not all sorts of solid substances capable of being excited?

Tutor. You may rub this poker, or the round ruler, for ever, without obtaining an electric spark from it.

James. But you said one might get a spark from the mahogany table, if it had more than its share.

Tutor. So I say you may have sparks from the poker, or ruler, if

they possess more than their common share of the electric fluid.

Charles. How do you distinguish between bodies that can be, and those that cannot be excited?

Tutor. The *former*, as I have told you, are called *electrics*, as the glass tube; the *latter*, such as the poker, the ruler, your body, and a thousand other substances, are denominated *couductors.*

Charles. I should be glad to know the reason of the distinction, because I shall be more likely to remember it.

Tutor. That is right: when you held your knuckle to the glass tube, you had several sparks from the different parts of it: but if I, by any means, overcharged a conductor, as this poker, all the electricity will

come away at a single spark, because the superabundant quantity flows instantaneously from every part to that point where it has an opportunity of getting away. I will illustrate this by an experiment. But first of all let me tell you, that all *electrics* are called also *non-conductors*.

James. Do you call the glass tube a *non-conductor*, because it does not suffer the electric fluid to pass from one part of it to another?

Tutor. I do: silk, if dry, is a non-conductor. With this skein of sewing-silk, I hang the poker, or other metal substance A (Plate I, Fig. 1), to a hook in the ceiling, so as to be about twelve inches from it; underneath, and near the extremity, are some small substances, as bits of paper, &c.

I will excite the glass tube, and present it to the upper part of the poker.

Charles. They are all attracted; but, now you take away the glass, they are quiet.

Tutor. It is evident that the electric fluid passed from one part of the tube through the poker, which is a conductor, to the paper, and attracted it:—if the glass be properly excited, you may take sparks from the poker.

James. Would not the same happen if another glass tube were placed in the stead of the poker?

Tutor. You shall try.—Now I have put the glass in the place of the poker, but let me excite the other tube as much as I will no effect can be produced on the paper:—there

are no signs of electrical attraction, which shows, that the electric fluid will not pass through glass.

Charles. What would have happened if any conducting substance had been used, instead of silk, to suspend the iron poker?

Tutor. If I had suspended the poker with a moistened hempen string, the electric fluid would have all passed away through that, and there would have been no (or very trifling) appearances of electricity at the end of the poker.

You may vary these experiments till you make yourselves perfect with regard to the distinction between electrics and conductors. Sealing-wax is an electric, and may be excited as well as a glass tube, and will produce similar effects. I will give you

a list of *electrics*, and another of *conductors*, disposed according to the order of their perfection, beginning in each list with the most perfect of their class: thus glass is a better *electric* than amber, and gold a better *conductor* than silver.

Electrics.	Conductors.
Glass of all kinds.	All the metals in the following order:
All precious stones, the most transparent the best.	Gold; silver;
Amber.	Copper; platina;
Sulphur.	Brass; iron;
All resinous substances.	Tin; quicksilver;
Wax of all kinds.	Lead.
Silk and cotton.	The semi-metals*.
Dry external substances, as feathers, wool, and hair.	Metallic ores*.
Paper; loaf sugar.	Charcoal.
Air, when quite dry.	The fluids of an animal body.
Oils and metallic oxides*.	Water, especially salt water, and other fluids, except oil.
Ashes of animal and vegetable substances.	Ice, snow.
Most hard stones.	Most saline substances.
	Earthy substances.
	Smoke; steam, and even a vacuum.

* This and other chemical terms are explained, and familiarly illustrated, in a work, by the author of the Scientific Dialogues, entitled "Dialogues in Chemistry," &c.

CONVERSATION III.

Of the Electrical Machine.

TUTOR. I will now explain to you the construction of the electrical machine, and show you how to use it.

Charles. For what purpose is it used?

Tutor. Soon after the subject of the electric fluid engaged the attention of men of science, they began to contrive the readiest methods of collecting large quantities of it. By

rubbing this stick of sealing-wax I can collect a small portion; if I excite or rub the glass tube, I get still more. The object, therefore, was to find out a machine by which the largest quantities can be collected, with as little trouble and expense as may be.

James. You get more electricity from the tube than from the sealing-wax, because it is five or six times as large: by increasing the size of the tube, you would increase the quantity of the electric fluid, I should think.

Tutor. That is a natural conclusion. But if you look to the table of electrics, which I made out yesterday, you will see, that, had the wax been as large as the glass tube, it would not have collected so much of

the electric fluid, because, in its own nature, it is not so good an electric.

Charles. In the Table, page 20, glass stands as the most perfect electric, but there are several substances between it and wax, all of which are, I believe, more perfect electrics than wax.

Tutor. They are: electricians, therefore, had no hesitation as to the nature of the substance: they fixed on glass, which, being easily melted and run, or blown into all sorts of forms, is, on that account, very valuable.

The most common form, that is now used, is that of a glass cylinder, from five or six inches in diameter to ten or twelve. Here is one completely fitted up (Plate I, Fig. 2), the

cylinder A B is about eight inches in diameter, and twelve or fourteen in length: this I turn round in the frame work, with the handle D C.

James. What is the piece of black silk K for?

Tutor. The cylinder would be of no use without a rubber you know: on which account you see the glass pillar R S, which, being cemented into a piece of hard wood, is made to screw into the bottom of the machine; on the pillar is a cushion, to which is attached a piece of black silk.

Charles. And I perceive the cushion is made to press very hard against the glass.

Tutor. This pressure, when the cylinder is turned round fast, acts precisely like the rubbing of the

tube by the hand, though in a still more perfect manner. I will turn it round.

James. Here is not much sign of electricity yet.

Tutor. No: the machine is complete, but it has no means of collecting the fluid from the surrounding bodies: for you see the cushion or rubber is fixed on a glass pillar, and glass will not conduct the electric fluid.

Charles. Nevertheless, it does, by turning round, show some signs of attraction.

Tutor. Every body in nature with which we are acquainted possesses a portion of this fluid, and therefore the signs, which are now evident, arise from the small quantity which exists in the rubber itself, and the

atmosphere that immediately surrounds the machine.

Charles. Would the case be different if the rubber were fixed on a conducting substance instead of glass?

Tutor. It would: but there is a much easier method: I will hang this brass chain to the cushion at R, which, being several feet long, lies on the table or on the floor, and this you know is connected, by means of other objects, with the earth, which is the grand reservoir of the electric fluid. Now see the effect of turning round the cylinder; but I must make every part of it dry and rather warm, by rubbing it with a dry warm cloth.

James. It is indeed very powerful. What a crackling noise it makes?

Tutor. Shut the window-shutters.

Charles. The appearance is very beautiful: the flashes from the silk dart all round the cylinder.

Tutor. I will now bring to the cylinder the tin conductor L, which is also placed on a glass pillar, F N, fixed in the stand at F.

James. What are the points in the tin conductor for?

Tutor. They are intended to collect the fluid from the cylinder. I will turn the cylinder, and do you hold your knuckle within four or five inches of the conductor.

Charles. The painful sensations, which these sparks occasion, prove that the electric fluid is a very powerful agent when collected in large quantities.

Tutor. To show you the nature

of conducting bodies, I will now throw another brass chain over the conductor, so that one end of it may lie on the floor. See now if you can get any sparks while I turn the machine.

James. No, I can get none, put my knuckle as near to it as I will.—Does it all run away by the chain?

Tutor. It does; a piece of brass or iron wire would do as well; and so would any conducting substance which touched the conductor with one end, and the floor with the other: your body would do as well as the chain. Place your hand on the conductor, while I turn round the cylinder: and let your brother bring his knuckle near the conductor.

Charles. I can get no spark.

Tutor. It runs through James to the earth, and you see his body is a conductor as well as the chain. With a very little contrivance I can take sparks from you or James, as well as you did from the conductor.

James. I should like to see how that is done.

Tutor. Here is a small stool, having a mahogany top and glass legs. If you stand on that, and put your hand on the conductor, the electricity will pass from the conductor to your body.

Charles. Will the glass legs prevent it from running from him to the earth.

Tutor. They will: and therefore what he receives from the conductor, he will be ready to part with to any of the surrounding bodies, or to you,

if you bring your hand near enough to any part of him.

James. The sparks are more painful in coming through my clothes, than when I received them on my bare hand.

Tutor. They are: you understand, I hope, the process.

Charles. By means of the chain trailing on the ground, the electric fluid is collected from the earth on the glass cylinder, which gives it through the points to the conductor; from this it may be conveyed away again by means of other conductors.

Tutor. Whatever body is supported, or prevented from touching the earth, or communicating with it, by means of glass, or other non-conducting substances, is said to be *insulated.* Thus, a body suspended on

a silk line is insulated, and so is any substance that stands on glass, or resin, or wax, provided that these are in a dry state, for moisture will conduct away the electric fluid from any charged body.

Hence you will understand the construction of electrical machines, which are so formed as by excitation to collect the fluid, which cannot escape again, owing to the glass cylinder, globe, or plate, being insulated.

CONVERSATION IV.

Of the Electrical Machine.

CHARLES. What is that shining stuff which I saw you put to the rubber yesterday?

Tutor. It is called *amalgam:* the rubber, by itself, would produce but a slight excitation: its power, however, is greatly increased by laying upon it a little of this amalgam, which is made of quicksilver, zinc, and tin-foil, with a little tallow or mutton suet.

James. Is there any art required in using this amalgam?

Tutor. When the rubber and silk flap are very clean and dry, and in their place, then spread a little of the amalgam upon a piece of leather, and apply it to the upper part of the glass cylinder while it is revolving from you; by this means, particles of the amalgam will be carried by the glass itself to the lower part of the rubber, and will increase the excitation.

Charles. I think I once saw a globe, instead of a cylinder, for an electrical machine.

Tutor. You might: globes were used before cylinders, but the latter are the more convenient of the two. The most powerful electrical machines are fitted with flat plates

of glass. In our experiments we shall be content with the cylinder, which will answer every purpose of explaining the principles of the science.

James. As I was able to conduct the electricity from the conductor to the ground, could I likewise act the part of the chain, by conducting the fluid from the earth to the cushion?

Tutor. Undoubtedly: I will take off the chain, and now do you keep your hand on the cushion while I turn the handle.

James. I see the machine works as well as when the chain was on the ground.

Tutor. Keep your present position, but stand on the stool with glass legs; by which means there

is now all communication cut off between the cushion and the earth; in other words the cushion is completely insulated, and can only take from you what electricity it can get from your body. Go, Charles, and shake hands with your brother.

Charles. It does not appear that the machine had taken all the electricity from him, for he gave me a smart spark.

Tutor. You are mistaken; he gave you nothing, but he took a spark from you.

Charles. I stood on the ground; I was not electrified: how then could I give him a spark?

Tutor. The machine had taken from James the electricity that was in his body, and, by standing on the

stool, that is by being insulated, he had no means of receiving any more from the earth, or any surrounding objects; the moment, therefore, you brought your hand near him the electricity passed from you to him.

Charles. I certainly felt the spark, but whether it went out of or entered into my hand, I cannot tell: have I then less than my share now?

Tutor. No: what you gave to your brother was supplied immediately from the earth. Here is another glass-legged stool; do you stand on this, but at the distance of a foot or two from your brother, who still keeps his place. I take the electricity from him by turning the machine, and, as he stands on the stool, he has now less than his share. But

you have your natural share, because, though you also are insulated, yet you are out of the influence of the machine; extend, therefore, your hand, and give him a part of the electric fluid that is in you.

Charles. I have given him a spark.

Tutor. And, being yourself insulated, you have now less than your natural quantity, to supply which, you shall have some from me: give me your hand. You draw it back without my touching it!

Charles. I did, but it was near enough to get a strong spark from you.

Tutor. When a person has *less* electricity than his natural share, he is said to be electrified *minus*, or negatively: but, if he has *more* than his

natural share, he is said to be electrified *plus*, or positively.

James. Then, before Charles gave me the spark, I was electrified minus; and, when he had given it me, he was minus till he received it from you.

Tutor. That is right. Suppose you stand on a stool and hold the rubber, and Charles stand on another stool, and touch the prime conductor L, while I turn the machine, which of you will be plus, and which minus electrified?

James. I shall be minus, because I give to the rubber; and Charles will be plus, because he receives from the conductor what I gave to the rubber, and which is carried by the cylinder to the conductor.

Tutor. You then have less than your share, and your brother has

more than he ought to have. Now, if I get another glass-legged stool, I can take from Charles what he has too much, and give it to you who have too little.

Charles. Is it necessary that you should be insulated for this purpose?

Tutor. By being insulated, I may, perhaps, carry back to James the very electricity which passed from him to you. But, if I stand on the ground, the quantity which I take from you will pass into the earth, because I cannot, unless I am insulated, retain more than my natural share.

James. And what is given by you to me is likewise instantaneously supplied by the earth.

Tutor. It is. Let us make an-

other experiment to show that the electric fluid is taken from the earth. Here are some little balls (Plate I, Fig. 3) made of the pith of elder: they are put on thread, and, being very light, are well adapted to our purpose.

While the chain is on the cushion, and I work the machine, do you bring the balls near the conductor, by holding the thread at D.

James. They are attracted by it, and now the two balls repel each other, as in the figure X.

Tutor. I ought to have told you, that the upper part D of the line is silk, by which means you know the balls are insulated, as silk is a non-conductor. I take the chain off from the cushion and put it on the conductor, so as to hang on the ground,

while I turn the machine. Will the balls be affected now, if you hold them to the conductor?

James. No, they are not.

Tutor. Take them to the cushion.

Charles. They are attracted and repelled now, by being brought near the cushion, as they were before, by being carried to the conductor.

Tutor. Yes, and you may take sparks from the cushion as you did just now from the conductor: in both cases it must be evident that the electric fluid is brought from the earth.

Some machines are furnished with two *conductors*, one of which is connected with the cushion, the other such as we have described. Turn the cylinder, and both conductors will be electrified; but any body

which is brought within the influence of these, will be attracted by one of the conductors, and repelled by the other: and, if a chain or wire be made to connect the two together, neither will exhibit any electric appearances: they seem, therefore, to be in opposite states; accordingly, electricians say, that the conductor connected with the cushion is negatively electrified, and the other is positively electrified.

Machines of this kind have been much used for medical purposes. But, on occasions when electricity is applied to the art of healing, there are several other instruments necessary, which will be described hereafter.

CONVERSATION V.

Of Electrical Attraction and Repulsion.

JAMES. What is this large roll of sealing-wax for?

Tutor. As I mean to explain, this morning, the principles of electrical attraction and repulsion, I have, besides the electrical machine, brought out for use a roll of sealing-wax, which is about fifteen inches long, and an inch and a quarter in diameter; and the long glass tube.

Charles. Are they not both electrics, and capable of being excited?

Tutor. They are; but the electricity produced by exciting them has different, or contrary properties.

James. Are there two kinds of electrics then?

Tutor. We will show you an experiment, before we attempt to give any theory.—I will excite the glass tube, and Charles shall excite the wax. Now do you bring the pith-balls, which are suspended on silk (Fig. 3), to the tube. They are suddenly drawn to it, and now they are repelled from one another, and likewise from the tube, for you cannot easily make them touch it again:—but take them to the excited wax.

James. The wax attracts them very powerfully: now they fall together again, and appear in the same state as they were in before they were brought to the excited tube.

Tutor. Repeat the experiment again and again, because, on this, two different theories have been formed. One of which is, that there are two electricities, called, by some philosophers, the *vitreous*, or positive electricity, and *resinous*, or negative electricity.

Charles. Why are they called *vitreous* and *resinous?*

Tutor. The word vitreous is Latin, and signifies any *glassy* substance; and the word *resinous*, used to denote that the electricity produced by resins, wax, &c., possesses different

qualities from that produced by glass.

James. Is it not natural to suppose that there are two electricities, since the excited wax attracts the very same bodies that the excited glass repels?

Tutor. It may be as easily explained, by supposing that every body, in its natural state, possesses a certain quantity of the electric fluid, and, if a part of it be taken away, it endeavours to get it from other bodies; or, if more be thrown upon it than its natural quantity, it yields it readily to other bodies that come within its influence.

Charles. I do not understand this.

Tutor. If I excite this glass tube, the electricity, which it exhibits, is supposed to come from my hand;

but, if I excite the roll of wax in the same way, the effect is, according to this theory, that a part of the electric fluid, naturally belonging to the wax, passes from it through my hand to the earth: and the wax, being surrounded by the air, which, in its dry state, is a non-conductor, remains exhausted, and is ready to take sparks from any body that may be presented to it.

James. Can you distinguish that the sparks came from the glass to the hand; and, on the contrary, from the hand to the wax?

Tutor. No: the velocity with which the electric spark moves, renders it impossible to say what course it takes; but I shall show you other experiments which seem to justify this theory: and, as Nature always

works by the simplest means, it seems more consistent with her usual operations, that there should be one fluid rather than two, provided that known facts can be equally well accounted for by one as by two.

Charles. Can you account for all the leading facts by either theory?

Tutor. Yes, we can. You saw, when the pith-balls were electrified, they repelled one another. It is a general principle in electricity, that two bodies, having more than their natural share of the electric fluid, will repel one another. But if one have more and the other less than its share they will attract one another.

James. How is this shown?

Tutor. I will hold this ball, which is insulated, by a silk thread, to the

conductor, and do you, Charles, do the same with the other. Let us now bring them together.

Charles. No, we cannot: they fly from one another.

Tutor. I will hold mine to the insulated cushion, and you shall hold yours to the conductor while the machine is turned: now I suspect they will attract one another.

James. They do indeed.

Charles. The reason is this; that the cushion, and whatever is in contact with it, parts with a portion of its electricity; but the conductor, and the adjoining bodies, have more than their share; therefore, the ball applied to the cushion, being negatively electrified, will attract the one connected with the conductor, which is positively electrified.

Tutor. Here is a tuft of feathers, which I stick in a small hole in the conductor; now see what happens when I turn the cylinder.

James. They all endeavour to avoid each other, and stand erect, in a beautiful manner. Let me take a spark from the conductor: now they fall down in a moment.

Tutor. When I turned the wheel, they all had more than their share of the electric fluid, and therefore they repelled one another; but the moment the electricity was taken away, they fell into their natural position. A large plume of feathers, when electrified, grows beautifully turgid, expanding its fibres in all directions, and they collapse when the electricity is taken off.

James. Could you make the hairs on my head repel one another.

Tutor. Yes, that I can. Stand on the glass-legged stool, and hold the chain that hangs on the conductor in your hand, while I turn the machine.

Charles. Now your hairs stand all an end.

James. And I feel something like cobwebs over my face.

Tutor. There are, however, no cobwebs, but that is the sensation which a person always experiences if he be highly electrified. Hold the pith-ball, Charles, near your brother's face.

James. It is attracted in the same manner as it was before with the conductor.

Tutor. Hence you may lay it

down as a general rule, that all light substances coming within the influence of an electrified body are attracted by it, whether it is electrified positively or negatively.

Charles. Because they are attracted by the positive electricity to receive some of the superabundant quantity; and by the negative to give away some that they possess.

Tutor. Just so: and when they have received as much as they can contain, they are repelled by the electrified body. The same thing may be shown in various ways. Having excited this glass tube, either by drawing it several times through my hand or by means of a piece of flannel, I will bring it near this small feather. See how quickly it jumps to the glass.

James. It does, and sticks to it.

Tutor. You will observe, that, after a minute or two, it will have taken as much electricity from the tube as it can hold, when it will suddenly be repelled, and jump to the nearest conductor; upon which it will discharge the superabundant electricity that it has acquired.

James. I see it is now going to the ground, that being the nearest conductor.

Tutor. I will prevent it, by holding the electrified tube between it and the floor. You see how unwilling it is to come again in contact with the tube: by pursuing I can drive it where I please without touching it.

Charles. That is, because the glass and the feather are both loaded with the same electricity.

Tutor. Let the feather touch the ground, or any other conductor, and you will see that it will jump to the tube, as fast as it did before.

I will suspend this brass plate, which is about five inches in diameter, to the conductor, and at the distance of three or four inches below I will place some small feathers, or bits of paper cut into the figures of men and women. They lie very quiet at present; observe their motions as soon as I turn the wheel.

James. They exhibit a pretty country dance: they jump up to the top plate, and then down again.

Tutor. The same principle is evident in all these experiments. The upper plate has more than its own share of the electric fluid, which attracts the little figures: as soon as

they have received a portion of it, they go down to give it to the lower plate; and so it will continue till the upper plate is discharged of its superabundant quantity.

I will take away the plates, and hang a chain on the conductor, the end of which shall lie in several folds in a glass tumbler; if I turn the machine, the electric fluid will run through the chain, and will electrify the inside of the glass. This done, I turn it quickly over eight or ten small pith-balls, which lie on the table.

Charles. That is a very amusing sight: how they jump about! They serve also to fetch the electricity from the glass, and carry it to the table.

Tutor. If, instead of the lower metal plate, I hold in my hand a pane of dry and very clean glass, by the cor-

ner, the paper figures, or pith-balls, will not move, because, glass being a non-conducting substance, it has no power of carrying away the superabundant electricity from the plate suspended from the conductor. But, if I hold the glass flat in my hand, the figures will be attracted and repelled, which shows that the electric fluid will pass through thin glass.

Take now the following results, and commit them to your memory.

(1.) If two insulated pith-balls be brought near the conductor, they will repel each other.

(2.) If an insulated conductor be connected with the cushion, and two insulated pith-balls be electrified by it, they will repel each other.

(3.) If one insulated ball be electrified by the prime conductor, and

another by the conductor connected with the cushion, and they be brought near, they will attract each other.

(4.) If one ball be electrified by glass, and another by wax, they will attract each other.

(5.) If one ball be electrified by a smooth, and another by a rough, excited glass tube, they will attract one another.

CONVERSATION VI.

Of Electrical Attraction and Repulsion.

TUTOR. I will show you another instance or two of the effects of electrical attraction and repulsion.

This apparatus (Plate I, Fig. 4) consists of three bells suspended from a brass wire, the two outer ones by small brass chains; the middle bell, and the two clappers, *x x*, are suspended on silk. From the middle bell there is a chain N, which goes to the table, or any other conducting

substance. The bells are now to be hung by c on the conductor, and the electrical machine to be put in motion.

James. The clappers go from bell to bell, and make very pretty music: how do you explain this?

Tutor. The electric fluid runs down the chains *a* and *b* to the bells AB; these having more than their natural quantity, attract the clappers *x x*, which take a portion from A and B, and carry it to the centre bell N, and this, by means of the chain, conveys it to the earth.

Charles. Would not the same effect be produced if the clappers were not suspended on silk?

Tutor. Certainly not: nor will it be produced if the chain be taken away from the bell N, because then

there is no way left to carry off the electric fluid to the earth.

Another amusing experiment is thus shown. Let there be two wires placed exactly one above another, and parallel; the upper one must be suspended from the conductor, the other is to communicate with the table. A light image placed between these will, when the conductor is electrified, appear like a rope-dancer.

This piece of leaf-brass is called the *electric fish*, one end is a sort of obtuse angle, the other is acute: if the large end be presented towards an electrified conductor, it will fix to it, and, from its wavering motion, will appear to be animated.

This property of attraction and repulsion has led to many inventions of instruments called electrometers,

James. Is not an electrometer a machine to measure the strength of the electricity?

Tutor. Yes; and this is one of the most simple (Plate 1, Fig. 5), and it depends entirely upon the repulsion which takes place between two bodies in a state of electrification. It consists of a light rod and a pith-ball, hanging parallel to the stem, but turning on the centre of a semicircle, so as to keep close to its graduated limb. This is to be placed in a hole *a* on the conductor L, and according as the conductor is more or less electrified, the ball will fly farther from the stem.

Charles. If the circular part be marked with degrees, you may ascertain, I suppose, pretty accurately, the strength of any given charge.

Tutor. Yes, you may; but you see how fast the air carries away the electricity; it scarcely remains a single moment in the place to which it was repelled. Two pith-balls may be suspended parallel to one another, on silken threads, and applied to any part of an electrical machine, and they will, by their repulsion, serve for an electrometer; for they will repel one another the more, as the machine acts more powerfully.

James. Has this any advantage over the other?

Tutor. It serves to show whether the electricity be negative or positive; for, if it be positive, by applying an excited stick of sealing-wax, the threads will fall together again; but, if it be negative, excited sealing-wax, or resin, or sulphur, or even a

rod of glass, the polish of which is taken off, will make them recede farther.

We have now perhaps said enough respecting electrical attraction and repulsion at least for the present; I wish you, however, to commit the following results to your memory.

(1.) Bodies that are electrified *positively* repel each other.

(2.) Bodies that are electrified *negatively* repel each other.

Charles. Do you mean, that, if two bodies have either more or less of the electric fluid than their natural share, they will repel each other, if brought sufficiently near?

Tutor. That is exactly what I mean.

(3.) Bodies electrified by contrary powers, that is, two bodies, one hav-

ing more, and the other less, than its natural share, attract each other very strongly.

(4.) Bodies that are electrified attract light substances which are not electrified.

These are facts which, I trust, have been made evident to your senses. To-morrow we will describe what is usually called the Leyden phial.

CONVERSATION VII.

Of the Leyden Phial, or Jar.

TUTOR. I will take away the wires and the ball from the conductor, and then remove the conductor an inch or two farther from the cylinder. If the machine acts strongly, bring an insulated pith-ball, that is, one hanging on silk, to the end of the conductor, nearest to the glass cylinder.

Charles. It is immediately attracted.

Tutor. Carry it to the other end of the conductor, and see what happens.

Charles. It is attracted again; but I thought it would have been repelled.

Tutor. Then, as the ball was electrified before, and is still *attracted*, you are sure that the electricity of the two ends of the conductor are of different names; that is, one is *plus*, and the other *minus*.

James. Which is the positive, and which is the negative end?

Tutor. That end of the conductor, which is nearest to the cylinder, becomes possessed of an electricity different from that of the cylinder itself.

James. Do you mean, that, if the

cylinder is positively electrified, the end of the conductor next to it is electrified negatively?

Tutor. I do: and this you may see by holding an insulated pith-ball between them.

Charles. Yes, it is now very evident, for the ball fetches and carries, as we have seen it before.

Tutor. What you have seen with regard to the conductor is equally true with respect to non-conducting bodies. Here is a common glass tumbler: If I throw withinside it a greater portion of electricity than its natural share, and hold it in my hand, or place it on any conducting substance, as a table, a part of the electric fluid, that naturally belongs to the outside, will make its

escape, through my body, on the table.

Charles. Let me try this.

Tutor. But you must be careful that you do not break the glass.

Charles. I will hang the chain on the conductor, and let the other end lie on the bottom of the glass, and James will turn the machine.

Tutor. You must take care that the chain does not touch the edge of the glass, because then the electric fluid will, by that means, run from one side of it to the other, and spoil the experiment.

James. If I have turned the machine enough, take the chain out, and try the two sides with the insulated pith-ball.

Charles. What is this? Something has pierced through my arms and shoulders.

Tutor. That is a trifling electrical shock, which you might have avoided, if you had waited for my directions.

Charles. Indeed it was not trifling; I feel it now.

Tutor. This leads us to the Leyden phial: so called because the discovery was first made at Leyden, in Holland, and by means of a phial or small bottle.

James. Was it found out in the same manner as Charles has just discovered it?

Tutor. Nearly so. Mr. Cuneus, a Dutch philosopher, was holding a glass phial in his hand, about half

filled with water, but the sides above the water, and the outside was quite dry, a wire also hung from the conductor of an electrical machine into the water.

James. Did that answer to the chain?

Tutor. Just so: and, like Charles, he was going to disengage the wire with one hand, as he held the bottle in the other, and was surprised and alarmed by a sudden shock in his arms, and through his breast, which he had not the least expected.

Charles. I do not think there was any thing to be alarmed at.

Tutor. The shock which he felt was, probably, something severer than that which you have just experienced: but the terror was evidently

increased by its coming so completely unexpected.

When M. Muschenbroek first felt the shock, which was by means of a thin glass bowl, and very slight, he wrote to M. Reaumur, that he felt himself struck in his arms, shoulders, and breast, so that he lost his breath, and was two whole days before he recovered from the effects of the blow.

Charles. Perhaps he meant the fright.

Tutor. Terror seems to have been the effect of the shock: for he adds, "I would not take a second shock, for the whole kingdom of France."

Mr. Ninkler, an experimental philosopher, at Leipsic, describes the shock as having given him convul-

sions, a heaviness in his head, such as he should feel if a large stone were on it, and he had reason to dread a fever, to prevent which he put himself on a course of cooling medicines. "Twice," says he, "it gave me a bleeding at the nose, to which I am not inclined; and my wife, whose curiosity surpassed her fears, received the shock twice, and found herself so weak, that she could scarcely walk. Nevertheless, in the course of a few days, she received another shock, which caused a bleeding at the nose."

James. Is this called the Leyden phial?

Tutor. It is. Leyden phials are now made in this manner (Plate I, Fig. 6): BA is a glass jar, both inside

and out are covered with tin-foil about three parts of the way up, as far as *x*.

Charles. Does the outside covering answer to the hand, and the inside covering to the water?

Tutor. They do. The piece of wood *z* is placed on the top, merely to support the brass wire and knob *v*, to the bottom of which hangs a chain that rests on the bottom of the jar. I will now set the jar in such a situation that it shall be within two or three inches of the conductor, while I work the machine.

James. The sparks fly rapidly from the conductor to the knob *v*.

Tutor. By that means, the inside of the jar becomes charged with a superabundant quantity of electricity: and, as it cannot contain this,

without, at the same time, driving away an equal quantity from the outside, the inside is positively electrified, and the outside is negatively electrified. To restore the equilibrium, I must make a communication between the outside and inside with some conducting substance; that is, I must make the same substance touch, at the same time, the outside tin-foil and that which is within, or, which is the same thing, another substance that does touch it.

Charles. The brass wire touches the inside: if I, therefore, with one hand touch the knob, and with the other the outside covering, will it be sufficient?

Tutor. It will: but I had rather you would not, because the shock will be more powerful than I should

wish either myself or you to experience. Here is a brass wire with two little balls or knobs *b s* screwed to it (Plate 1, Fig. 7); I will bring one of them, as *s* to the outside, and the other, *b*, to the ball *v* on the wire.

James. What a brilliant spark, and what a loud noise!

Tutor. The electric fluid, that occasions the light and the noise, ran from the inside of the jar through the wire to *s*, and spread itself over the outside.

Charles. Would it have gone through my arms if I had put one hand to the outside, and touched the wire communicating with the inside with the other?

Tutor. It would, and you may conceive that the shock would have

been in proportion to the quantity of the fluid collected. The instrument I used may be called a discharging-rod. But here is a more convenient one (Plate 1, Fig. 8): the handle D is solid glass, fastened into a brass socket, and the brass work is the same as Fig. 7, only, by turning on a joint, the arms may be opened to any extent.

James. Why is the handle glass?

Tutor. Because glass, being a non-conductor, the electric fluid passes through the brass work without affecting the hand; whereas, with the other, a small sensation was perceived while I discharged the jar.

Charles. Would the jar never discharge itself?

Tutor. Yes; by exposure to the air for some time, the charge of the

jar will be silently and gradually dissipated, for the superabundant electric fluid of the inside will escape, by means of the air, to the outside of the jar.—But electricians make it a rule never to leave a jar in its charged state.

James. What is the reason of this rule?

Tutor. To prevent accidents. A person coming into the room unawares, by touching a charged jar, might reeeive a shock, that, under peculiar circumstances, might be attended with dangerous consequences.

CONVERSATION VIII.

Of the Leyden Jar. — Lane's Discharging Electrometer, and the Electrical Battery.

CHARLES. In discharging the jar yesterday, I observed that, when one of the discharging-rods touched the outside of the jar, the flash and report took place before the other end came in contact with the brass wire that communicates with the inside coating.

Tutor. Yes, it acts in the same manner as when you take a spark

from the conductor; you do not, for that purpose, bring your knuckle close to the tin.

James. Sometimes, when the machine acts very powerfully, you may get the spark at the distance of several inches.

Tutor. By the same principle, the higher an electrical or Leyden jar is charged, the more easily, or at a greater distance, is it discharged.

Charles. From your experiments it does not seem that it will discharge at so great a distance as that in which a spark may be taken from the conductor.

Tutor. Very frequently a jar will discharge itself, after it has accumulated as much of the electrical fluid as it can contain; that is, the fluid which is thrown on the inside coat-

ing will make its way over the glass, though a non-conductor, on to the outside coating.

James. In a Leyden jar, after the first discharge, you always, I perceive, take another and smaller one.

Tutor. The tin-foil on the jar not being a perfect conductor, the whole quantity of fluid will not pass at first from the inside to the out: what remains is called the *residuum*, and this, in a large jar, would give you a considerable shock; therefore, I advise you always, in discharging an electrical jar, to take away the residuum before you venture to remove the apparatus. I will now describe an electrometer, which depends, for its action, on the principles we have been describing.

Charles. Do you mean upon the jar's discharging before the outside and inside coating are actually brought into contact?

Tutor. I do. (Plate I, Fig. 10.) The arm D is made of glass, and proceeds from a socket on the wire of the electrical jar F. To the top of the glass arm is cemented another brass socket E, through which a wire, with balls B and C at each end, will slide backwards and forwards.

James. So that it may be brought to any distance from the ball A, which is on the wire, connected with the inside of the jar?

Tutor. Just so. When the jar F is set either in contact, or very near the conductor, as it is represented in the figure, and the ball B is set at the distance of the eighth of an inch

from the ball A, let a wire C K be fixed between the ball C and the outside coating of the jar. Then, as soon as the machine is worked, the jar cannot be charged beyond a certain point, for when the charge is strong enough to pass from A to the ball B, the discharge will take place, and the electric fluid, collected in the inside, will pass through the wire C K to the outside coating.

Charles. If you remove the balls to a greater distance from one another, will a stronger charge be required before the fluid can pass from the inside of the jar to the ball B of the electrometer?

Tutor. Certainly: and therefore the discharge will be much stronger. This machine is called Lane's Discharging Electrometer, from the

name of the person who invented it. It is very useful in applying the electric shock to medical purposes, as we shall see hereafter.

This box contains nine jars or Leyden phials (Plate I, Fig. 9): the wires, which proceed from the inside of each three of these jars, are screwed or fastened to a common horizontal wire E, which is knobbed at each extremity; and, by means of the wires F F, the inside coatings of 3 or 6, or the whole 9, may be connected.

James. Is it a common box in which the jars are placed?

Tutor. The inside of the box is lined with tin-foil; sometimes very thin tin-plates are used, for the purpose of connecting more effectually the outside coatings of all the jars.

Charles. What is the hook c on one of the sides of the box for?

Tutor. To this hook is fastened a strong wire, which communicates with the inside lining of the box, and of course with the outside coating of the jars. And, as you see, to the hook a wire is also fastened, which connects it with one branch of the discharging-rod.

James. Is there any particular art to be used in charging a battery?

Tutor. No: the best way is to bring a chain, or piece of wire, from the conductor to one of the balls on the rods that rest upon the jars; and then set the machine to work. The electric fluid passes from the conductor to the inside of all the jars, till it is charged sufficiently high for the purpose. Great caution, however,

must be used when you come to make experiments with a battery, for fear of an accident, either to yourself, or to spectators.

Charles. Would a shock from this be attended with any bad consequences?

Tutor. Yes: very serious accidents may happen from the electricity accumulated in a large battery, and even with a battery such as is represented in the plate, which is one of the smallest made, a shock may be given, which, if passed through the head, or other vital parts of the body, may be attended with very mischievous effects.

James. How do you know when the battery is properly charged?

Tutor. The quadrant electrometer (Plate I, Fig. 5) is the best guide, and

this may be fixed either on the conductor or upon one of the rods of the battery. But, if it is fixed on the battery, the stem of it should be of a good length, not less than twelve or fifteen inches.

Charles. How high will the index stand when the battery is charged?

Tutor. It will seldom rise so high as 90°, because a machine, under the most favourable circumstances, cannot charge a battery so high, in proportion, as a single jar. You may reckon that a batterry is well charged when the index rises as high as 60°, or between that and 70°.

James. Is there no danger of breaking the jars when the battery is very highly charged?

Tutor. Yes, there is; and, if one jar be cracked, it is impossible to

charge the others, till the broken one be removed. To prevent accidents, it is recommended not to discharge a battery through a good conductor, except the circuit is at least five feet long.

Charles. Do you mean the wire should be so long?

Tutor. Yes, if you pass the charge through a wire; but you may carry it through any conductor.

Before a battery be used, the uncoated part of the jars must be made perfectly clean and dry: the smallest particles of dust or moisture will carry away the electric fluid. And, after an explosion, take care always to connect the wire on the hook with the ball, to prevent any residuum from remaining.

James. Have not small animals

been sometimes killed by an electrical battery?

Tutor. Yes; rats and mice, and pigeons have been killed instantly with discharges from a battery.

CONVERSATION IX.

Experiments made with the Electrical Battery.

TUTOR. I will now show you some experiments with this large battery. To perform these in perfect safety I must beg you to stand a good distance from it: this will prevent accidents.

Ex. 1. I take this quire of writing-paper, and place it against the hook or wire that comes out of the box; and when the battery is charged

I put one ball of the discharging-rod to a knob of one of the wires F, and bring the other knob to that part of the paper that stands against the wire proceeding from the box. You see what a hole it has made through every sheet of the paper. Smell the paper where the perforation is.

Charles. It smells like sulphur.

Tutor. Or more like phosphorus. You observe, in this experiment, that the electric fluid passed from the inside of the jars, through the conducting-rod, and paper, to the outside.

James. Why did it not pass through the paper in the same manner as it passed the brass discharging-rod, in which it made no hole?

Tutor. Paper is a non-conducting substance, but brass is a conductor: through the latter it passes without any resistance, and, in its endeavour to get to the inside of the box, it burst the paper. The same thing would have happened, had there been twice or thrice as much paper. The electric fluid of a single jar will pierce through many sheets of paper.

Charles. Would it serve any other non-conducting substance in the same manner?

Tutor. Yes, it will even break a thin piece of glass, or of resin, or of sealing-wax, if it be interposed between the discharging-rod and the outside of the coating of the battery.

Ex. 2. Place a piece of loaf-sugar in the situation in which the quire of paper was just now, the sugar will be broken, and in the dark it will appear beautifully illuminated, and remain so for many seconds of time.

Ex. 3. Let the small piece of wire, proceeding from the hole in the box, be laid on one side of a plate, containing some spirits of wine, and, on the opposite side of the plate, bring one of the knobs of the discharging-rod, while the other is carried to the wires connected with the inside of the jars.

Charles. Then the electric fluid will have a passage through the spirit?

Tutor. It will set it on fire instantly.

Ex. 4. Take two slips of common window-glass, about four inches long, and one inch broad: put a slip of gold-leaf between the glasses, leaving a small part of it out at each end; then tie the glasses together, or press them with a heavy weight, and send the charge of the battery through it, by connecting one end of the glass with the outside of the jars, and bringing the discharging-rod to the other end, and to the wires of the inside of the battery.

James. Will it break the glass?

Tutor. It probably will; but whether it does or not, the gold leaf will be forced into the pores of the glass, so as to appear like glass stained with gold which nothing can wash away.

Ex. 5. If the gold-leaf be put between two cards, and a strong charge passed through it, it will be completely fused or melted, the marks of which will appear on the card.

This instrument (Plate I, Fig. 11), called a universal discharger, is very useful for passing charges through many substances. B B are glass pillars cemented into the frame A. To each of the pillars is cemented a brass cap, and a double joint for horizontal and vertical motion; on the top of each joint is a spring tube, which holds the sliding wires C *x*, C *x*, so that they may be set at various distances from each other, and turned in any direction; the extremities of the wires are pointed, but with screws, at about half an inch

from the points, to receive balls. The table E D, inlaid with a piece of ivory, is made to move up and down in a socket, and a screw fastens it to any required height. The rings C C are very convenient for fixing a chain or wire to them, which proceeds from the conductor.

Charles. Do you lay any thing on the ivory, between the balls, when you want to send the charges of a battery through it?

Tutor. Yes; and by drawing out the wires the balls may be separated to any distance less than the length of the ivory. The figure H. (Plate I, Fig. 12) represents a press, which may be substituted in the place of the table E D. It consists of two flat pieces of mahogany, which may be brought together by screws.

James. Then, instead of tying the slips of glass together in Ex. 4, you might have done it better by making use of the press?

Tutor. I might; but I was willing to show you how the thing could be done, if no such apparatus as this were at hand. The use of the table and press, which, in fact, always go together, is for keeping steady all descriptions of bodies through which the charge of a single jar, or any number of which a battery consists, is to be conveyed. We will now proceed with the experiments.

Ex. 6. I will take the knobs from the wires of the universal discharger, and, having laid a piece of very dry writing-paper on the table E, I place the points of the wires at an inch or more from one

another; then, by connecting one of the rings c with the outside wire or hook of the battery, and bringing the discharging-rod from the other ring c to one of the knobs of the battery, you will see that the paper will be torn to pieces.

Ex. 7. The experiment, which I am now going to make, you must never attempt by yourselves. I put a little gunpowder in the tube of a quill open at both ends, and insert the pointed extremities of the two wires in it, so as to be within a quarter of an inch or less from each other. I now send the charge of the battery through it, and the gunpowder, you see, is instantly inflamed.

Ex. 8. Here is a very slender wire, not a hundredth part of an inch in diameter, which I connect

with the wires of the discharger, and send the charge of a battery through it, which will completely melt it, and you now perceive the little globules of iron instead of the thin wire.

Charles. Will other wires besides iron be melted in the same manner?

Tutor. Yes, if the battery be large enough, and the wires sufficiciently thin, the experiment will succeed with them all: even with a single jar, if it be pretty large, very slender wire may be fused. But the charges of batteries have been used to determine the different conducting powers of the several metals.

James. If the charge is not strong enough to melt the wire, will it make it red hot?

Tutor. It will: and, when the ex-

periment is properly done, the course of the fluid may be discerned by its effects: for, if the wire is about three inches long, it will be seen that the end of it, which is connected with the inside of the battery, is red hot first, and the redness proceeds towards the other.

Charles. That is a clear proof that the superabundant electricity accumulated in the inside is carried to the outside of the jars.

Tutor. Ex. 9. We have, in the last volume, discussed the subject of magnetism: and we may here observe, that, by discharging the battery through a small sewing needle, it will become magnetic; that is, if the needle be accurately suspended on a small piece of cork in a bason of water, one end will, of itself, point

to the north and the other to the south.

Ex. 10. I will lay this chain on a sheet of writing-paper, and send the charge of the battery through the chain; and you will see black marks will be left on the paper in those places where the rings of the chain touch each other.

Ex. 11. Place a small piece of very dry wood between the balls of the universal dischargers, so that the fibres of the wood may be in the direction of the wires, and pass the charge of the battery through them, the wood will be torn in pieces. The points of the wires being run into the wood, and the shock passed through them, will effect the same thing.

Ex. 12. Here is a glass tube, open at both ends, six inches long,

and a quarter of an inch in diameter. These pieces of cork, with wires in them, exactly fit the ends of the tube. I put in one cork, and fill the tube with water, then put the other cork in, and push the wires so that they nearly touch and pass the charge of the battery through them; you see the tube is broken, and the water dispersed in every direction*.

Charles. If water is a good conductor, how is it that the charge did not run through it without breaking the tube?

Tutor. The electric fluid, like common fire, converts the water into a

* To prevent accidents, a wire cage, such as is used in some experiments on the air-pump, should be put over the tube before the discharge is made: young persons should not attempt this experiment by themselves.

highly elastic vapour, which, occupying very suddenly a much larger space than the water, bursts the tube before it can effect any means of escape.

In some instances, the electric fluid decomposes the water, which is instantly converted into two elastic gases, that occupy a vast deal more space than the water from which they are produced.

CONVERSATION X.

Of the Electric Spark, and Miscellaneous Experiments.

TUTOR. I wish you to observe some facts connected with the electric spark. By means of the wire inserted in this ball I fix it to the end of the conductor, and bring either another brass ball, or my knuckle to it, and, if the machine act pretty powerfully, a long, crooked, brilliant spark, will pass between the

two balls, or between the knuckle and ball. If the conductor is negative, it receives the spark from the body; but, if it is positive, the ball or the knuckle receives the spark from the conductor.

Charles. Does the size of the spark depend at all on the size of the conductor?

Tutor. The longest and largest sparks are obtained from a large conductor, provided the machine act very powerfully. When the quantity of electricity is small, the spark is straight; but when it is strong, and capable of striking at a greater distance, it assumes what is called a zig-zag direction.

James. If the electric fluid is fire, why does not the spark, which ex-

cities a painful sensation, burn me, when I receive it on my hand?

Tutor. Ex. 1. I have shown you that the charge from a battery will make iron wire red-hot, and inflame gunpowder. Now stand on the stool with glass legs, and hold the chain from the conductor with one hand. Do you, Charles, hold this spoon, which contains some spirits of wine, to your brother, while I turn the machine, and a spark taken from his knuckle, if large, will set fire to the spirit.

Charles. It has indeed. Did you do nothing with the spirit?

Tutor. I only made the silver spoon pretty warm before I put the spirit into it.

Ex. 2. If a ball of box wood be

placed on the conductor instead of the brass ball, a spark taken from it will be of a fine red colour.

Ex. 3. An ivory ball placed on the conductor will be rendered very beautiful and luminous, if a strong spark be taken through its centre.

Ex. 4. Sparks taken over a piece of silver leather appear of a green colour, and over gilt leather of a red colour.

Ex. 5. Here is a glass tube (Plate 1, Fig. 13), round which, at small distances from each other, pieces of tin-foil are pasted in a spiral form, from end to end: this tube is enclosed in a larger one, fitted with brass cups at each end, which are connected with the tin-foil of the inner tube.—I hold one end A in

my hand, and while one of you turn the machine, I will present the other end B to the conductor, to take sparks from it.—But first shut the window-shutters.

Charles. This is a very beautiful experiment.

Tutor. The beauty of it consists in the distance which is left between the pieces of tin-foil; and, by increasing the number of these distances, the brilliancy is very much heightened.

Ex. 6. The following is another experiment of the same kind. Here is a word, with which you are acquainted (Plate II, Fig. 14), made on glass, by means of tin-foil pasted on glass, fixed in a frame of baked wood. I hold the frame in my hand

at H, and present the ball G to the conductor, and at every considerable spark the word is beautifully illuminated.

Ex. 7. A piece of sponge filled with water, and hung to a conductor, when electrified in a dark room, exhibits a beautiful appearance.

Ex. 8. This bottle is charged: if I bring the brass knob that stands out of it to a bason of water which is insulated it will attract a drop: and on the removal of the bottle, it will assume a conical shape, and, if brought near any conducting substance, it will fly to it in luminous streams.

Ex. 9. Place a drop of water on the conductor, and work the machine, the drop will afford a long

spark, assume a conical figure, and carry some of the water with it.

Ex. 10. On this wire I have fixed a piece of sealing-wax, and, having fixed the wire into the end of the conductor, I will light the wax, and the moment the machine is worked the wax will fly off in the finest filaments imaginable.

Ex. 11. I will wrap some cotton-wool round one of the knobs of my discharging-rod, and fill the wool with finely bruised resin; I now discharge a Leyden jar, or a battery, in the common way, and the wool is instantly in a blaze. The covered knob must touch the knob of the jar, and the discharge should be effected as quickly as possible.

You will remember that the electric fluid always chooses the nearest

road, and the best conductors to travel by; in proof of which take the following experiment:—

Ex. 12. With this chain I make a sort of w (Plate 1, Fig. 15), the wire *w* touches the outside of a charged jar, and the wire *x* is brought to the knob of the jar, and in the dark a brilliant w is visible. But if the wire *w* is continued to *m*, the electric fluid takes a shorter road to *x*, and of course only half of the w is seen, *viz.* that part marked *m z y*: but if, instead of the wire *w m*, a dry stick be laid in its place, the electric matter will prefer a longer circuit, rather than go through a bad conductor, and the whole w will be illuminated.

Ex. 13. Here is a two-ounce phial, half full of sallad-oil; through the cork

is passed a piece of slender wire, the end of which, within the phial, is so bent as to touch the glass just below the surface of the oil. I place my thumb opposite the point of the wire in the bottle, and in that position take a spark from the charged conductor. You observe that the spark, to get to my thumb, has actually perforated the glass. In the same way I can make holes all round the phial.

Charles. Would the experiment succeed with water instead of oil?

Tutor. No, it would not.

James. At any rate we see the course of the electric fluid in this experiment, for the spark comes from the conductor down the wire, and through the glass to the thumb.

Tutor. Its direction is, however, better shown in this way:—

Ex. 14. At that end of the conductor, which is farthest from the machine, I fix a brass wire about six inches long, having a small brass ball on its extremity. To this ball, when the machine is at work, I hold the flame of a wax taper.

Charles. The flame is evidently blown from the ball, in the direction of the electric fluid: it has a similar effect to the blast of a pair of bellows.

Ex. 15. I will fix a pointed wire upon the prime conductor, with the point outward, and another like wire upon the insulated rubber. Shut the window-shutter, and I will work the machine: now observe the points of the two wires.

James. They both are illuminated, but differently. The point on the conductor sends out a sort of brush

of fire, but that on the rubber is illuminated with a star.

Tutor. You see, then, the difference between the positive and negative electricity. Their appearances are sufficiently distinct in almost every experiment which can be made. If a strong positive electric stream be thrown on the flat side of an uninsulated sheet of paper, it will form a star: but negative electricity, under the same circumstances, throws out brushes.

CONVERSATION XI.

Miscellaneous Experiments — Of the Electrophorus — Of the Electrometer and the Thunder House.

TUTOR. I shall proceed this morning with some other experiments on the electrical machine.

Ex. 1. Here are two wires, one of which is connected with the outside of this charged Leyden jar, the other is so bent as easily to touch the knob of the jar. The two straight ends I bring within the distance of the tenth of an inch of one another,

and press them down with my thumb, and in this position, having darkened the room, I discharge the jar. Do you look upon my thumb.

Charles. It was so transparent that I think I even saw the bone of the thumb.—But did it not hurt you very much?

Tutor. With attention, you might observe the principal blood-vessels, I believe; and the only inconvenience that I felt was a sort of tremor in my thumb, which is by no means painful. Had the wires been at double the distance, the shock would have probably made my thumb the circuit, which must have caused a more powerfu. and unpleasant sensation; but, being so close, the electric fluid leaped from one wire to the other, and during this passage it illuminated

my thumb, but did not go through it.

Ex. 2. If, instead of my thumb, a decanter full of water, having a flat bottom, were placed on the wires, and the discharge made, the whole of the water will be beautifully illuminated.

Ex. 3. This small pewter bucket is full of water, and I suspend it from the prime conductor, and put in a glass syphon, with a bore so narrow that the water will hardly drop out. See what will happen when I work the machine; but first make the room dark.

James. It runs now in a full stream, or rather in several streams, all of which are illuminated.

Tutor. Ex. 4. If the knob *a* (Plate II, Fig. 16) communicate with

the outside of a charged Leyden jar, and the knob *b* with the inside coating, and each be held about two inches from the lighted candle *x*, and opposite to one another, the flame will spread towards each, and a discharge will be made through it: this shows the conducting power of flame.

This instrument (Plate II, Fig. 17), which consists of two circular plates, of which the largest B is about fifteen inches in diameter, and the other A fourteen inches, is called an *electrophorus*. The *under* plate B is made of glass, or sealing-wax, or of any other non-conducting substance: I have made one with a mixture of pitch and chalk boiled together, which answers very well. The upper plate A is sometimes made of

brass and sometimes of tin plate, but this is of wood, covered very neatly with tin-foil: *x* is a glass handle fixed to a socket, by which the upper plate is removed from the under one.

Charles. What do you mean by an electrophorus?

Tutor. It is, in fact, a sort of simple electrical machine, and is thus used. Rub the lower plate B with a fine piece of new flannel, or with rabbit's, or hare's, or cat's skin, and when it is well excited, place upon it the upper plate A, and put your finger on the upper plate: then remove this plate by the glass handle *x*, and, if you apply your knuckle, or the knob of a coated jar, you will obtain a spark. This operation may be repeated many times,

without exciting again the under plate.

James. Can you charge a Leyden jar in this way?

Tutor. Yes, it has been done, and by a single excitation, so as to pierce a hole through a card by means of the jar thus charged.

Here is another kind of electrometer (Plate II, Fig. 18), which is by far the most sensible that has been yet invented; that is, it is capable of discovering the smallest quantities of electricity. A is a glass jar, B the cover of metal, to which are attached two pieces of gold-leaf *x*, or two pith-balls suspended on threads: on the sides of the glass jar are two narrow strips of tin-foil.

Charles. How is this instrument used?

Tutor. Any thing that is electrified is to be brought to the cover, which will cause the piece of gold-leaf or pith-balls to diverge; and the sensibility of this instrument is so great, that the brush of a feather, the throwing of chalk, hair-powder, or dust, against the cap B, evinces strong signs of electricity.

Ex. 5. Place on the cap B a little pewter or any other metallic cup, having some water in it: then take from the fire a live cinder, and put it in the cup, and the electricity of vapour is very admirably exhibited.

A thunder cloud passing over this instrument will cause the slips of

gold-leaf to diverge and strike the sides at every flash of lightning.

Ex. 6. I will excite this stick of sealing-wax, and bring it to the cover B: you see how often it causes the gold-leaf to strike against the sides of the glass.

James. Are the slips of tin-foil intended to carry away the electric fluid communicated by the objects presented to the cap B?

Tutor. They are, and by them the equilibrium is restored.

CONVERSATION XII.

Of Atmospherical Electricity.

CHARLES. You said yesterday, that the electrometer was affected by thunder and lightning: are lightning and electricity similar?

Tutor. They are, undoubtedly, the same fluid; and that they are the same was discovered by Dr. Franklin almost seventy years ago.

James. How did he ascertain this fact?

Tutor. He was led to the theory from observing the power which

uninsulated *points* have in drawing off the electricity from bodies. And having formed his system, he was waiting for the erection of a spire, in Philadelphia, to carry his views into execution, when it occurred to him that a boy's kite would answer his purpose better than a spire. He therefore prepared a kite, and having raised it, he tied to the end of the string a silken cord, by which the kite was completely insulated. At the junction of the two strings he fastened a key as a good conductor, in order to take sparks from it.

Charles. Did he obtain any sparks?

Tutor. One cloud, which appeared like a thunder-cloud, passed without any effect; shortly after, the loose threads of the hempen string stood erect, in the same manner as they

would if the string had been hung on an electrified insulated conductor. He then presented his knuckle to the key, and obtained an evident spark. Others succeeded before the string was wet, but, when the rain had wetted the string, he collected the electricity very plentifully:—

——Led by the phosphor light, with daring tread,
Immortal Franklin sought the fiery bed;
Where, nurs'd in night, incumbent tempest shrouds
The seeds of thunder in circumfluent clouds,
Besieg'd with iron points his airy cell,
And pierc'd the monster slumb'ring in the shell.

DARWIN.

James. Could I do so with our large kite?

Tutor. I hope you will not try

to raise your kite during a thunder storm, because, without very great care, it may be attended with the most serious danger. Your kite is, however, quite large enough, being four feet high, and two feet wide: every thing depends on the string, which, according to Mr. Cavallo, who has made many experiments on the subject, should be made of two thin threads of twine, twisted with a copper thread. And to Mr. Cavallo's work on electricity, vol. II, such persons as are desirous of raising kites, for electrical purposes, should be referred, in which they will find ample instruction.

Charles. How do the conductors, which I have seen fixed to various buildings, act in dispersing lightning?

Tutor. You know how easy it is

to charge a Leyden jar: but if, when the machine is at work, a person hold a point of steel, or other metal, near the conductor, the greater part of the fluid will run away by that point instead of proceeding to the jar. Hence it was concluded, that pointed rods would silently draw away the lightning from clouds passing over any building.

James. Is there not a particular method of fixing them?

Tutor. Yes: the metallic rod must reach from the ground, or the nearest piece of water, to a foot or two above the building it is intended to protect, and the iron rod should come to a fine point. Some electricians recommend that the point should be of gold, to prevent its rusting.

Charles. What effects would be

produced, if lightning should strike a building without a conductor?

Tutor. That may be best explained, by informing you of what happened, many years ago, to St. Bride's church. The lightning first struck the weathercock; from thence, descending in its progress, it beat out a number of large stones of different heights, some of which fell upon the roof of the church, and did great damage to it. The mischief done to the steeple was so considerable, that eighty-five feet of it were obliged to be taken down.

James. The weathercock was probably made of iron, why did not that act as a conductor?

Tutor. Though that was made of iron, yet it was completely insulated by being fixed in stone, which had be-

come dry by much hot and dry weather. When, therefore, the lightning had taken possession of the weathercock, by endeavouring to force its way to another conductor, it beat down whatever stood in its way.

Charles. The power of lightning must be very great.

Tutor. It is irresistible in its effects: the following experiment will illustrate what I have been saying:—

Ex. 1. A is a board (Plate II, Fig. 19) representing the gable end of a house: it is fixed on another board B: *a b c d* is a square hole, to which a piece of wood is fitted; *a d* represents a wire fixed diagonally on the wood *a b c d*; *x b*, terminated by a knob *x*, represents a weathercock, and the wire *c z* is fixed to the board A.

It is evident that, in the state in which it is drawn in the figure, there is an interruption in the conducting rod; accordingly, if the chain *m* is connected with the outside of a Leyden phial, and then that phial is discharged through *x*, by bringing one part of the discharging rod to the knob of the Leyden phial, and the other to within an inch or two of *x*, the piece of wood *a b c d* will be thrown out with violence.

James. Are we to understand by this experiment, that if the wire *x b* had been continued to the chain, that the electric fluid would have run through it without disturbing the loose board?

Tutor. Ex. 2. Just so; for if the piece of wood be taken out, and the part *a* be put to the place *b*, then *d*

will come to *c*, and the conducting rod will be complete, and continued from *x* through *b c* to *z*, and now the phial may be discharged as often as you please, but the wood will remain in its place, because the electric fluid runs through the wire to *z*, and makes its way by the chain to the outside of the phial.

Charles. Then, if *x* be supposed the weathercock of the church, the lightning having overcharged this, by its endeavours to reach another conductor, as *c z*, forced away the stone or stones represented by *a b c d*?

Tutor. That is what I meant to convey to your minds by the first experiment; and the second shows very clearly, that, if an iron rod had gone from the weathercock to the ground, without interruption, it would have

conducted away the electricity silently, and without doing any injury to the church.

James. How was it that all the stones were not beat down?

Tutor. Because, in its passage downwards, it met with many other conductors. I will read part of what Dr. Watson says on this fact, who examined it very attentively:—

"The lightning," says he, "first took a weathercock, which was fixed at the top of the steeple, and was conducted without injuring the metal or any thing else, as low as where the large iron bar, or spindle, which supported it, terminated: there the metallic communication ceasing, part of the lightning exploded, cracked and shattered the obelisk, which terminated the spire of the steeple, in

its whole diameter, and threw off, at that place, several large pieces of Portland stone. Here it likewise removed a stone from its place, but not far enough to be thrown down. From thence the lightning seemed to have rushed upon two horizontal iron bars, which were placed within the building cross each other. At the end of one of these iron bars it exploded again, and threw off a considerable quantity of stone. Almost all the damage was done where the ends of the iron bars had been inserted into the stone, or placed under it; and, in some places, its passage might be traced from one iron bar to another."

The thunder holds his black tremendous throne:
From cloud to cloud the rending lightnings rage;

Till, in the furious elemental war
Dissolv'd, the whole precipitated mass
Unbroken floods and solid torrents pours.
THOMSON.

Electricity manifests itself more frequently without storms than with them; it is produced oftener by dry than by rainy clouds: it is more frequently positive than negative. The atmosphere exhibits signs of electricity at all times, by night and by day.

CONVERSATION XIII.

On Atmospheric Electricity.—Of Falling Stars—Of the Aurora Borealis—Of Water-spouts and Whirlwinds—Of Earthquakes.

CHARLES. Does the air always contain electricity?

Tutor. Yes; and it is owing to the electricity of the atmosphere that we observe a number of curious and interesting phenomena, such as falling stars; the aurora borealis, or north-

ern lights: the ignus fatuus, or Will-with-the-wisp.

James. I have frequently seen what people call falling stars, but I never knew that they were occasioned merely by electricity.

Tutor. These are seen chiefly in clear and calm weather: it is then that the electric fluid is probably not very strong, and, passing through the air, it becomes visible in particular parts of its passage, according to the conducting substances it may meet with. One of the most striking phenomena of this kind is recorded by Signior Beccaria.—As he was sitting with a friend in the open air, an hour after sun-set, they saw a falling, or, as it is sometimes called, a shooting star, directing its course to-

ward them, growing, apparently, larger and larger, till it disappeared not far from them, and, disappearing, it left their faces, hands, and clothes, with the earth and neighbouring objects, suddenly illuminated with a diffused and lambent light, attended with no noise at all.

Charles. But how did he know that this was only the effect of electricity?

Tutor. Because he had previously raised his kite, and found the air very much charged with the electric matter: sometimes he saw it advancing to his kite like a falling star; and sometimes he saw a kind of glory round it, which followed it as it changed its place.

James. Since lofty objects are ex-

posed to the effects of lightning, or the electric fluid, do not the tall masts of ships run considerable risk of being struck by it?

Tutor. Certainly: we have many instances recorded of the mischief done to ships; one of which is related in the Philosophical Transactions: it happened on board the Montague, on the 4th of November, 1748, in lat. 42° 48′ and 9° 3′ west longitude, about noon. One of the quarter-masters desired the master of the vessel to look to the windward, when he observed a large ball of blue fire rolling apparently on the surface of the water, at the distance of three miles from them. It rose almost perpendicular when it was within forty or fifty yards from the main-

chains of the ship, it then went off with an explosion, as if a hundred cannon had been fired at one time, and left so strong a smell of sulphur, that the ship seemed to contain nothing else. After the noise had subsided, the main top-mast was found shattered to pieces, and the mast itself was rent quite down to the keel. Five men were knocked down, and one of them greatly burnt by the explosion.

Charles. Did it not seem to be a very large ball to have produced such effects?

Tutor. Yes: the person who noticed it said it was as big as a millstone.

The aurora borealis is another electrical phenomenon: this is ad-

mitted without any hesitation, because electricians can readily imitate the appearance with their experiments.

James. It must be, I should think, on a very small scale.

Tutor. True: there is a glass tube about thirty inches long, and the diameter of it is about two inches; it is nearly exhausted of air, and capped on both ends with brass. I now connect these ends, by means of a chain, with the positive and negative part of a machine; and in a darkened room, you will see, when the machine is worked, all the appearances of the northern lights in the tube.

Charles. Why is it necessary nearly to exhaust the tube?

Tutor. Because the air, in its natural state, is a very bad conductor of the electric fluid; but when it is, perhaps, rendered some hundred times rarer than it usually is, the electric fluid darts from one cap to the other with the greatest ease.

James. But we see the aurora borealis in the common air.

Tutor. We do so; it is, however, in the higher regions of the atmosphere, where the air is much rarer than it is near the surface of the earth. The experiment, which you have just seen, accounts for the darting and undulating motion which takes place between the opposite parts of the heavens. The aurora borealis is the most beautiful and brilliant in countries

in the high northern latitudes, as in Greenland and Iceland.

Charles. I remember the lines on this subject:—

By dancing meteors, then, that ceaseless shake
A waving blaze refracted o'er the heav'ns,
And vivid moons, and stars that keener play
With double lustre from the glossy waste,
Ev'n in the depth of polar night, they find
A wond'rous day; enough to light the chase,
Or guide their daring steps to Finland fairs.

Tutor. The aurora borealis, that was seen in this country on the 23d of October, in the year 1804, is deserving of notice. At seven in the evening a luminous arch was seen from the centre of London extending from one point of the horizon, about s. s. w. to another point N. N. W

and passing the middle of the constellation of the Great Bear, which it, in a great measure, obscured. It appeared to consist of shining vapour, and to roll from the south to the north. In about half an hour, its course was changed; it then became vertical, and about nine o'clock it extended across the heavens from N. E. to S. W.; at intervals, the continuity of the luminous arch was broken, and there then darted from its south-west quarter, towards the zenith, strong flashes and streaks of bright red, similar to what appears in the atmosphere during a great fire in any part of the metropolis. For several hours the atmosphere was as light in the south-west as if the sun had set but half an hour; and the

light in the north resembled the strong twilight which marks that part of the horizon at Midsummer. Thomson, speaking of the aurora borealis, and other meteors, says—

——————— Silent from the north
A blaze of meteors shoots; ensweeping first
The lower skies, they all at once converge
High to the crown of heaven, and all at once
Relapsing quick, as quickly reascend,
And mix and thwart, extinguish and renew,
All æther coursing in a maze of light.

James. How do you account, Sir, for the Will-with-the wisp, or Jack-a-lanthorn, that is close to the ground, where the air is thickest?

Tutor. This is a meteor, which seldom appears more than six feet

above the ground; it is always about bogs and swampy places, and these, in hot weather, emit what is called hydrogen gas, or inflammable air, which is easily inflamed by the electric spark. These, therefore, as you shall see in our chemical experiments, we can as readily imitate as the aurora borealis.—In some parts of Italy, meteors of this kind are frequently very large, and give a light equal to that of a torch.

Water spouts, which are sometimes seen at sea, are supposed to arise from the power of electricity.

Charles. I have heard of these, but I thought that water-spouts at sea, and whirlwinds and hurricanes by land, were produced solely by the force of the wind.

Tutor. The wind is, undoubtedly, one of the causes, but it will not account for every appearance connected with them. Water-spouts are often seen in calm weather, when the sea seems to boil, and send up a smoke under them, rising in a sort of hill towards the spout. A rumbling noise is often heard at the time of their appearance, which happens generally in those months that are peculiarly subject to thunder-storms, and they are commonly accompanied or followed by lightning. When these approach a ship, the sailors present and brandish their swords to disperse them, which seems to favour the conclusion, that they are electrical.

James. Do the swords act as conductors?

Tutor. They may, certainly; and

it is known, that, by these pointed instruments, they have been effectually dispersed.

The analogy between the phenomena of water-spouts and electricity may be made visible by hanging a drop of water to a wire, communicating with the prime conductor, and placing a vessel of water under it. In these circumstances, the drop assumes all the various appearances of a water-spout, in its rise, form, and mode of disappearing.

Water-spouts, at sea, are undoubtedly very like whirlwinds and hurricanes by land. These sometimes tear up trees, throw down buildings, make caverns; and, in all the cases, they scatter the earth, bricks, stones, timber, &c., to a great distance in every direction. Dr. Franklin mentions a

remarkable appearance which occurred to Mr. Wilke, a considerable electrician. On the 20th of July, 1758, at three o'clock in the afternoon, he observed a great quantity of dust rising from the ground, and covering a field, and part of the town in which he then was. There was no wind, and the dust moved gently towards the east, where there appeared a great black cloud, which electrified his apparatus positively to a very high degree. This cloud went towards the west, the dust followed it, and continued to rise higher and higher, till it composed a thick pillar in the form of a sugar-loaf, and at length it seemed to be in contact with the cloud. At some distance from this there came another great cloud, with a long stream of

smaller ones, which electrified his apparatus negatively, and when they came near the positive cloud, a flash of lightning was seen to dart through the cloud of dust, upon which the negative clouds spread very much, and dissolved in rain, which presently cleared the atmosphere.

Charles. Is rain, then, an electrical phenomenon?

Tutor. The most enlightened and best informed electricians reckon rain, hail, and snow, among the effects produced by the electric fluid.

James. Do the negative and positive clouds act in the same manner as the outside and inside coatings of a charged Leyden-jar?

Tutor. Thunder-clouds frequently do nothing more than conduct or

convey the electric matter from one place to another.

Charles. Then they may be compared to the discharging-rod.

Tutor. And perhaps, like that, they are intended to restore the equilibrium between two places, one of which has too much, and the other too little of the electric fluid. The following is not an uncommon appearance: a dark cloud is observed to attract others to it, and when grown to a considerable size, its lower surface swells in particular parts towards the earth. During the time that the cloud is thus forming, flashes of lightning dart from one part of it to the other, and often illuminate the whole mass; and small clouds are observed moving rapidly beneath it. When the cloud has acquired a sufficient extent,

the lightning strikes the earth in two opposite places.

James. I wonder the discharge does not shake the earth, as the charge of a jar does any thing through which it passes.

Tutor. Every discharge of clouds through the earth may do this, though it is imperceptible to us.

Earthquakes are probably occasioned by vast discharges of the electric fluid: they happen most frequently in dry and hot countries, which are subject to lightning, and other electric phenomena: they are even foretold by the electric coruscations, and other appearances in the air for some days preceding the event. Besides, the shock of an earthquake is instantaneous to the greatest distances. Earthquakes are usually accompa-

nied with rain, and sometimes by the most dreadful thunder-storms: these, and other circumstances, but especially the almost instantaneous motion of the shock, lead to the inference, that electricity is the cause, as being the only power in nature that acknowledges no sensible transition of time in its operations.

How greatly terrible, how dark and deep
The purposes of Heaven! At once o'erthrown
White age and youth, the guilty and the just,
Oh, seemingly severe! promiscuous fall.
Reason, whose daring eye in vain explores
The fearful providence, confus'd, subdu'd
To silence and amazement, with due praise
Acknowledges th' Almighty, and adores
His will unerring, wisest, justest, best.

MALLET.

CONVERSATION XIV.

Medical Electricity.

TUTOR. If you stand on the stool with glass legs, and hold the chain from the conductor while I work the machine a few minutes, your pulse will be increased; that is, it will beat more frequently than it did before. From this circumstance physicians have applied electricity to the cure of many disorders; in some of which their endeavours have been unavailing, in others the success has been very complete.

Charles. Did they do nothing more than this?

Tutor. Yes, in some cases they took sparks from their patients, in others they gave them shocks.

James. This would be no pleasant method of cure, if the shocks were strong.

Tutor. You know, by means of Lane's electrometer, described in our seventh Conversation (Plate 1, Fig. 10), the shock may be given as slightly as you please.

Charles. But how are shocks conveyed through any part of the body?

Tutor. There are machines and apparatus made purposely for medical purposes, but every end may be answered by the instrument just referred to. Suppose the electrometer to be fixed to a Leyden phial, and the knob

at A (Fig. 10) to touch the conductor, and the knob B to be so far off as you mean the shocks to be weak or strong, a chain or wire of sufficient length is to be fixed to the ring C of the electrometer, and another wire or chain to the outside coating: the other ends of these two wires are to be fastened to the two knobs of the discharging-rod.

James. What next is to be done, if I wish to electrify my knee, for instance?

Tutor. All you have to do is to bring the balls of the discharging-rod close to your knee, one on the one side, and the other on the opposite side.

Charles. And, at every discharge of the Leyden jar, the superabundant electricity from withinside will pass

from the knob at A to the knob B, and will pass through the wire and the knee, in its way to the outside of the jar, to restore to both sides an equilibrium.

James. But if it happen that a part of the body, as an arm, is to be electrified, how is it to be done, because, in that case, I cannot use both my hands in conducting the wires?

Tutor. Then you may seek the assistance of a friend, who will, by means of two instruments, called *directors*, be able to conduct the fluid to any part of the body whatever.

Charles. What are directors?

Tutor. A director consists of a knobbed brass wire, which, by means of a brass cap, is cemented to a glass handle. So the operator, holding

these directors by the extremities of the glass handle, brings the balls, to which the wires or chains are attached, into contact with the extremities of that part of the body of the patient through which the shock is to be sent. If I feel rheumatic pains between my elbow and wrist, and a person hold one director at the elbow and another about the wrist, the shocks will pass through, and probably will be found useful in removing the complaint.

James. Is it necessary to stand on the glass-footed stool to have this operation performed?

Tutor. By no means: when shocks are administered, the person who receives them may stand as he pleases, either on the stool, or on the ground; the electric fluid, taking the nearest

passage, will always find the other knob of the other director, which leads to the outside of the jar.

Charles. Is it necessary to make the body bare?

Tutor. Not in the case of shocks, unless the coverings be very thick; but, when sparks are to be taken, then the person from whom they are drawn must be insulated, and the clothes should be stripped off the part affected.

James. For what disorders are the shocks and sparks chiefly used?

Tutor. Shocks have been found useful in paralytic disorders; in contractions of the nerves; in sprains, and in many other cases; but great attention is necessary in regulating the force of the shock, because, instead of advantage, mis-

chief may occur, if it be too violent.

Charles. Is there less danger with sparks?

Tutor. Yes; for unless it be in very tender parts, as the eye, there is no great risk in taking sparks: and they have proved very effectual in removing many complaints.

The celebrated Mr. Ferguson was seized, at Bristol, with a violent sore throat, so as to prevent him from swallowing any thing: he caused sparks to be taken from the part affected, and in the course of an hour he could eat and drink without pain.

This is an excellent method in cases of deafness, ear-ache, tooth-ache, swellings inside the mouth, &c.

James. Would not strong sparks injure the ear?

Tutor. They might; and therefore the electric fluid is usually drawn with a pointed piece of wood, to which it comes in a stream, or, when sparks are taken, a very small brass ball is used, because, in proportion to the size of the ball, is the size of the spark.

The chief difficulty in administering electricity, in a medical view, consists in distinguishing the proper strength of the electric power that is required for a given disorder.

CONVERSATION XV.

Of Animal Electricity: of the Torpedo; of the Gymnotus Electricus, and of the Silurus Electricus.

TUTOR. There are three kinds of fish, which have been discovered, that are possessed of the singular property of giving shocks very similar to those experienced by means of the Leyden jar.

Charles. I should like much to see them: are they easily obtained?

Tutor. No, they are not: they are called the *torpedo*, the *gymnotus electricus*, and the *silurus electricus.*

James. Are they all of the same genus?

Tutor. No: the torpedo is a flat fish, seldom twenty inches long, and is common in various parts of the sea coast of Europe. The electric organs of this fish are placed on each side of the gills, where they fill up the whole thickness of the animal, from the lower to the upper surface, and are covered by the common skin of the body.

Charles. Can you lay hold of the fish by any other part of the body with impunity?

Tutor. Not altogether so: for, if it be touched with one hand, it generally communicates a very slight

shock; but if it be touched with both hands at the same time, one being applied to the under, and the other to the upper surface of the body, a shock will be received similar to that which is occasioned by the Leyden jar.

James. Will not the shock be felt if both hands be put on one of the electrical organs at the same time?

Tutor. No: and this shows that the upper and lower surfaces of the electric organs are in opposite states of electricity, answering to the positive and negative sides of a Leyden phial.

Charles. Are the same substances conductors of the electric power of the torpedo, by which artificial electricity is conducted?

Tutor. Yes, they are: and, if the fish, instead of being touched by the hands, be touched by conducting substances, as metals, the shock will be communicated through them. The circuit may also be formed by several persons joining hands, and the shock will be felt by them all at the same time. But the shock will not pass where there is the smallest interruption; it will not even be conducted through a chain.

James. Can you get sparks from it?

Tutor. No spark was ever obtained from the torpedo, nor could electric repulsion and attraction be produced by it.

Charles. Is it known how the power is accumulated?

Tutor. It seems to depend on the

will of the animal, for each effort is accompanied with a depression of its eyes, and it probably makes use of it as a means of self-defence.

James. Is this the case also with the other electrical fishes?

Tutor. The *gymnotus* possesses all the electric properties of the torpedo, but in a very superior degree. This fish has been called the electrical eel, on account of its resemblance to the common eel. It is found in the large rivers of South America.

Charles. Are these fishes able to injure others by this power?

Tutor. If small fishes are put into the water in which the gymnotus is kept, it will first stun, or perhaps kill them, and, if the animal be hungry, it will then devour them. But fishes stunned by the gymnotus may be reco-

vered, by being speedily removed into another vessel of water.

The gymnotus is said to be possessed of a new kind of sense, by which it knows whether bodies, which are brought near it, are conductors or not.

Charles. Then it possesses the same knowledge by instinct which philosophers have gained by experiment.

Tutor. True. The following experiment, among others, is very decisive on this point.

Ex. The extremities of two wires were dipped into the water of the vessel in which the animal was kept; they were then bent, extended a great way, and terminated in two separate glasses full of water. These wires, being supported by non-conductors,

at a considerable distance from each other, the circuit was incomplete: but if a person put their fingers of both hands into the glasses in which the wires terminated, then the circuit was complete. While the circuit was incomplete the fish never went near the extremities of the wires, as if desirous of giving the shock; but the moment the circuit was completed, either by a person, or any other conductor, the gymnotus immediately went toward the wires, and gave the shock, though the completion of the circuit was out of his sight.

James. How do they catch these kind of fish; the men would, probably, let them go on receiving the shock?

Tutor. In this way the property was, perhaps, first discovered. The

gymnotus, as well as the others, may be touched, without any risk of the shock, with wax or with glass; but, if it be touched with the naked finger, or with a metal, or a gold ring, the shock is felt up the arm.

Charles. Does the *silurus electricus* produce the same effects as the others?

Tutor. This fish is found in some rivers in Africa, and it is known to possess the property of giving the shock, but no other particulars have been detailed respecting it.

With regard to the torpedo, its power of giving the benumbing sensation was known to the ancients, and from this it probably took its name.—In Fermin's Natural History of Surinam is some account of the *trembling-eel*, which Dr. Priestly conjectures

to be different from the gymnotus; it lives in marshy places, from whence it cannot be taken, except when it is intoxicated. It cannot be touched with the hand, or with a stick, without feeling a terrible shock. If trod upon with shoes, the legs and thighs are affected in a similar manner.

CONVERSATION XVI.

General Summary of Electricity, with Experiments.

TUTOR. You now understand what electricity is?

Charles. Yes, it is a fluid which seems to pervade all substances, and, when undisturbed, it remains in a state of equilibrium.

James. And that certain portion, which every body is supposed to contain, is called its natural share.

Tutor. When a body is possessed of more, or retains less, than its natural share, it is said to be *charged*, or electrified.

Charles. If it possess more than its natural share, it is said to be *positively* electrified, but, if it contain less than its natural share, it is said to be *negatively* electrified.

Tutor. Does it not sometimes happen, that the same substance is both positively and negatively electrified at the same time?

James. Yes: the Leyden jar is a striking instance of this, in which, if the inside contain more than its natural share, the outside will contain less than its natural quantity.

Tutor. What is the distinction between conductors and non-conductors of electricity?

Charles. The electric fluid passes freely through the *former*, but the *latter* oppose its passage.

Tutor. You know that electricity is excited in the greatest quantities, by the friction of conducting and non-conducting substances against each other.

Ex. Rub two pieces of sealing-wax, or two pieces of glass together, and only a very small portion of electricity can be obtained; therefore the rubber of a machine should be a conducting substance, and not insulated.

Every electrical machine, with an insulated rubber, will act in three different ways: the rubber will produce *negative* electricity: the conductor will give out *positive* electricity: and it will communicate both

powers at once to a person or substance placed between two directors connected with them.

James. How does the rubber produce negative electricity?

Tutor. If you stand on a stool with glass legs, or upon any other non-conducting substance, and lay hold of the rubber, or a chain that communicates with it, the working the machine will take away from you a quantity of your natural electricity: therefore you will be negatively electrified.

Charles. Will this appear by the nature of the electric fluid, if I hold in my hand a steel point, as a needle?

Tutor. If you, standing on a non-conducting substance, are connected with the rubber, and your brother, in a similar situation, con-

nected with the conductor, hold points in your hands, and I, while I stand on the ground, first present a brass ball, or other substance, to the needle in your hand, and then to that in his hand, the appearance of the fluid will be different in both cases: to the needle in your hand it will appear like a star, but to that in your brother's it will be rather in the form of a brush.—What will happen if you bring two bodies near to one another that are both electrified?

James. If they are both positively or both negatively electrified, they will repel each other, but, if one is negative and the other positive, they will attract one another till they touch, and the equilibrium is again restored.

Tutor. If a body, containing only its natural share of electricity, be brought near to another that is electrified, what will be the consequence?

Charles. A quantity of electricity will force itself through the air, in the form of a spark.

Tutor. When two bodies approach each other, one electrified positively and the other negatively, the superabundant electricity rushes violently from one to the other to restore the equilibrium. What will happen if your body, or any part of it, form part of the circuit?

James. It will produce an electric shock, and if, instead of one person alone, many join hands, and form a part of the circuit, they will all receive a shock at one and the same instant.

Tutor. If I throw a larger quantity of electricity than its natural share on one side of a piece of glass, what will happen to the other side?

Charles. The other side will become negatively electrified: that is, it will have as much less than its natural share, as the other has more than its natural share.

Tutor. Does electricity communicated to glass spread over the whole surface?

James. No; glass being an excellent non-conductor, the electric fluid will be confined to the part on which it is thrown: and for that reason, and in order to apply it to the whole surface, the glass is covered with tin-foil, which is called a *coating.*

Tutor. And if a conducting com-

munication be made between both sides of the glass, what takes place then?

Charles. A discharge; and this happens whether the glass be flat, or in any other form.

Tutor. What do you call a cylindrical glass vessel thus coated for electrical purposes?

James. A Leyden jar; and when the insides, and also the outsides, of several of these jars are connected, it is called an electrical battery.

Tutor. Electricity, in this form, is capable of producing the most powerful effects, such as melting metals, firing spirits, and other inflammable substances.—What effect have metallic points on electricity?

Charles. They discharge it silently, and hence their great utility in

defending buildings from the dire effects of lightning.—Pray what is thunder?

Tutor. As lightning appears to be the rapid motion of vast masses of electric matter, so thunder is the noise produced by the motion of lightning; and when electricity passes through the higher parts of the atmosphere, where the air is very much rarefied, it constitutes the aurora borealis.

Ex. If two sharp-pointed wires be bent (Plate II, Fig. 30), with the four ends at right angles, but pointing different ways, and they be made to turn upon a wire fixed on the conductor, the moment it is electrified, a flame will be seen at the points *a b c d*; the wire will begin to turn

round in the direction opposite to that to which the points are turned, and the motion will become very rapid.

If the figures of horses cut in paper be fastened upon these wires, the horses will seem to pursue one another, and this is called the electrical horse-race. Of course, upon this principle many other amusing and very beautiful experiments may be made: and upon this principle several electrical orreries have been contrived, showing the motions of the earth and moon, and the earth and planets round the sun.

James. How do you account for this?

Tutor. Fix a sharp-pointed wire into the end of the large conductor,

and hold your hand near it: no sparks will ensue; but a cold blast will come from the point, which, when applied to light mills, wheels, &c., will turn them with great velocity.

GALVANISM, OR VOLTAISM.

CONVERSATION I.

Of Galvanism; its Origin: Experiments.—Of the Decomposition of Water.

TUTOR. It has been observed, as long as I can remember, and probably before I was born, that porter, when taken from a pewter pot, had a superior flavour than when drunk out of glass or of china.

Charles. Yes, I have often heard people say so: but what is the reason of it?

Tutor. Admitting the fact, which is, I believe, generally allowed by those who are much accustomed to that beverage, it is now explained upon the principles of *Galvanism.*

James. Is Galvanism another branch of science? Is there a Galvanic fluid as well as an electric fluid?

Tutor. Of the existence of the electric fluid you now have no doubt; the science of electricity took its name from *electron*, the Greek word for amber, because amber was one of the first substances observed to produce, by rubbing, the effects of attraction and repulsion. Galvanism derives its name from Dr. Galvani, who first reported to the philosophical world the experiments on which the science is founded.

Charles. Pray how was he led to make the experiments?

Tutor. Galvani, a professor of anatomy at Bologna, was one evening making some electrical experiments, and on the table where the machine stood were some frogs skinned: by an accident, one of the company touched the main nerve of a frog, at the same moment that he took a considerable spark from the conductor of the electrical machine, and the muscles of the frog were thrown into strong convulsions. These, which were observed by Galvani's wife, led the professor to a number of experiments, but, as they cannot be repeated without much cruelty to living animals, I shall not enter into a detail of them.

James. Were not the frogs dead which first led to the discovery?

Tutor. Yes, they were: but the professor afterwards made many experiments upon living ones, whence he found, that the convulsions, or, as they are usually called, the contractions produced on the frog, may be excited without the aid of any apparent electricity, merely by making a communication between the nerves and the muscles with substances that are *conductors* of electricity.

Charles. Which are the best conducting substances?

Tutor. All the metals: but zinc and silver, or zinc and copper, produce the greatest muscular contractions.

Charles. Are these experiments peculiar to frogs?

Tutor. No; they have been suc-

cessfully made on almost all kinds of animals, from the ox downwards to the fly. And hence it was at first concluded, that there was an electricity peculiar to animals.

James. You have already shown that the electric fluid exists in our bodies, and may be taken from them, independently of that which causes the contractions.

Tutor. I will show you an experiment on this subject:—here is a thin piece of *zinc*, which is a sort of metallic substance, but not what is denominated a perfect metal: lay it *under* your tongue, and lay this half-crown *upon* the tongue; do you taste any thing very peculiar in the metals?

James. No, nothing at all.

Tutor. Put them in the same position again, and now bring the edges

of the two metals in contact, while the other parts touch the under and upper surface of the tongue.

James. Now they excite a very disagreeable taste, something like copperas.

Tutor. Instead of the half-crown, try the experiment with a guinea, or with a piece of charcoal.

Charles. I perceive the same kind of taste which James described. How do you explain the fact?

Tutor. Some philosophers maintain, that the principle of Galvanism and electricity is the same: and that the former is the evolution or emission of the electric fluid from *conducting* bodies, disengaged by a chemical process: while the latter is the same thing made apparent to the senses by *non-conducting* bodies.

James. All metals, as we have seen, are conducting substances: of course, the zinc, the guinea, and the half-crown are conductors.

Tutor. Yes, and so are the tongue and the saliva; and it is probable, that, by the decomposition of some small particles of the saliva, the sharp taste is excited.

Charles. What do you mean by the decomposition of the saliva?

Tutor. We have, in our Chemistry, shown, that water is capable of being decomposed, that is, separated into two gases, called hydrogen and oxygen.

James. Is saliva capable of being thus separated?

Tutor. Certainly, because a great part of it may be supposed to be water; and the oxygen combines

with the metal while the hydrogen escapes, and excites the taste on the tongue.

Charles. The disagreeable taste on the tongue cannot be disputed, but there is no apparent change on the zinc or the half-crown, which there ought to be if a new substance, as the oxygen, has entered into the combination.

Tutor. The change is, perhaps, too small to be perceived in this experiment: but in others on a larger scale, it will be very evident to the sight, by the *oxidation* of the metals.

James. Here is another strange word. I do not know what is meant by oxidation.

Tutor. The iron bars fixed before the window were clean and al-

most bright when placed there last summer.

James. But not being painted they are become quite rusty.

Tutor. Now, in chemical language, the iron is said to be oxidated instead of rusty; and the earthy substance, that may be scraped from them, used to be called the *calx* of iron; but it is, by modern chemistry, denominated the oxide of iron.

When mercury loses its fine brightness, by being long exposed to the air, the dulness is occasioned by oxidation; that is, the same effect is produced by the air on the mercury, as was on the iron. I will give you another instance. I will melt some lead in this ladle, you see a scum is speedily formed. I take it away, and another will arise, and so perpetually till the

whole lead is thus transformed into an apparently different substance: this is called the oxide of lead.

On the same principle we obtain the oxides of the other metals, and the process by which the metals are converted into oxides is called oxidation. The pure metals, as silver and gold, are not easily oxidated: but lead, copper, iron, zinc, &c., readily lose their metallic properties, and become oxides.

CONVERSATION II.

Galvanic Light and Shocks—Voltaism.

CHARLES. We had a *taste* of the Galvanic fluid yesterday, is there no way of seeing it?

Tutor. Put this piece of zinc between the upper lip and the gums, as high as you can, and then lay a half-crown, or guinea, upon the tongue, and, when so situated, bring the metals into contact.

Charles. I thought I saw a faint flash of light.

Tutor. I dare say you did, it was

for that purpose I bade you make the experiment. It may be done in another way; by putting a piece of silver up one of the nostrils, and the zinc on the upper part of the tongue, and then, bringing the metals in contact, the same effect will be produced.

James. By continuing the contact of the two metals, the appearance of light does not remain.

Tutor. No, it is visible only at the moment of making the contact. You may, if you make the experiment with great attention, put a small slip of tinfoil over the ball of one eye, and hold a tea-spoon in your mouth, and then, upon the communication between the spoon and the tin, a faint light will be visible. These experiments are best performed in the dark.

Charles. Is there no means of making experiments on a larger scale?

Tutor. Yes, we have Galvanic, or, as they ought to be denominated, *Voltaic* batteries, from Volta*, the inventor of them, as well as electrical batteries. Here is one of them. (Plate II, Fig. 20.) It consists of a number of pieces of silver, zinc, and flannel cloth, of equal sizes; and they are thus arranged: a piece of zinc, a piece of silver, and a piece of cloth, moistened with a solution of salt in water, and so on till the pile is com-

* Galvani's discoveries were the result of mere accident, and even but trifling, in comparison of those made by Volta, a celebrated Italian, who improved the few hints before him into an important body of science: hence the term Voltaism has already, in a great measure, superseded that of Galvanism.

pleted. To prevent the pieces from falling, they are supported on the sides by three rods of glass stuck into a piece of wood, and down these rods slides another piece of wood, which keeps all the pieces in close contact.

James. How do you make use of this instrument?

Tutor. Touch the lower piece of metal with one hand, and the upper one with the other.

James. I felt an electric shock.

Tutor. And you may take as many as you please; for, as often as you renew the contact, so often will you feel the shock.

Here is a different apparatus. (Plate II, Fig. 21.) In these three glasses (and I might use twenty instead of three) is a solution of salt and water. Into each, except the two outer ones,

is plunged a small plate of zinc, and another of silver. These plates are made to communicate with each other by means of a thin wire, fastened so that the silver of the first glass is connected with the zinc of the second; the silver of the second with the zinc of the third, and so on: now, if you dip one hand into the first glass, and the other into the last, the shock is felt.

Charles. Will any kind of glasses answer for the experiment?

Tutor. Yes, they will; wine-glasses, or goblets, or finger glasses; and so will china cups.

A third kind of battery, which is the most powerful, and the one that is most generally used, is this. It consists of a trough of baked wood, three inches deep, and about as

broad. In the sides of this trough are grooves opposite to each other, and about a quarter of an inch asunder. Into each pair of these grooves is put a plate of zinc, and another of silver, and they are to be cemented in such a manner as to prevent any communication between the different cells. The cells are now filled with a solution of salt and water. The battery is complete; with your hands make a communication between the two end cells.

Charles. I felt a strong shock.

Tutor. Wet your hands, and join your left with James's right, then put your right hand into one end cell, and let James put his left into the opposite one.

James. We both felt the shock like an electric shock, but not so severe.

Tutor. Several persons may receive the shock together, by joining hands, if their hands are well moistened with water. The strength of the shock is much diminished by passing through so long a circuit. The shock from a battery, consisting of fifty or sixty pairs of zinc and silver, or zinc and copper, may be felt as high as the elbows. And, if five or six such batteries be united with metal cramps, the combined force of the shock would be such that few would willingly take it a second time.

Charles. What are the wires for at each end of the trough?

Tutor. With these, a variety of experiments may be made upon combustible bodies. I will show you one with gunpowder, but I must have

recourse to four troughs, united by cramps, or to one much larger than this.

Towards the ends of the wires are two pieces of glass tubes: these are for the operator to hold by, while he directs the wires. Suppose now four or more troughs united, and the wire to be at the two extremities, I put some gunpowder on a piece of flat glass, and then, holding the wires of the glass tubes, I bring the ends of them to the gunpowder, and, just before they touch, the gunpowder will be inflamed.

Instead of gunpowder, gold and silver leaf may be burnt in this way: ether, spirits of wine, and other inflammable substances, are easily fired by the Voltaic battery;

it will consume even small metallic wires.

Copper or brass-leaf, commonly called Dutch gold, burns with a beautiful green light, silver with a pale blue light, and gold with a yellowish green light.

James. Will the battery continue to act any great length of time?

Tutor. The action of all these kind of batteries is the strongest when they are first filled with the fluid; and it declines in proportion as the metals are oxidated, or the fluid loses its power. Of course, after a certain time, the fluid must be changed and the metals cleaned, either with sand, or by immersing them a short time in diluted muriatic acid. The best fluid for filling the cells with is water mixed with one-

tenth of nitrous acid. Care must always be taken to wipe quite dry the edges of the plates, to prevent a communication between the cells: and it will be found, that the energy of the battery is in proportion to the rapidity with which the zinc is oxidated.

CONVERSATION III.

Voltaic Conductors— Circles—Tables —Experiments.

TUTOR. You know that *conductors* of the electric fluid differ from each other in their conducting power.

Charles. Yes, the metals are the most perfect conductors, then charcoal, afterwards water and other fluids.—See p. 20.

Tutor. In Voltaism we call the former *dry* and *perfect* conductors,

these are the first class: the latter, or second class, *imperfect* conductors: and, in rendering the Voltaic power sensible, the combination must consist of at least three conductors of the different classes.

James. Do you mean two of the first class, and one of the second?

Tutor. When two of these bodies are of the first class, and one is of the second, the combination is said to be of the *first order.*

Charles. The large battery which you used yesterday was of the *first order* then, because there were two metals, *viz.* zinc and silver, and one fluid.

Tutor. This is called a *simple Voltaic circle,* the two metals touched each other in some points, and at other points they were connected by

the fluid, which was of a different class.

James. Will you give us an example of the second order?

Tutor. When a person drinks porter from a pewter mug, the moisture of his under lip is one conductor of the second class, the porter is the other, and the metal is the third body, or conductor of the first class.

The discoloration of a silver spoon, in the act of eating eggs, is a Voltaic operation. A spoon merely immersed in the egg undergoes no discoloration, it is the act of eating that produces the change. This is a Voltaic combination of the second order, the fluid egg, and the saliva, are substances of the second class of conductors, and the silver of the first class.

Charles. Which are the most powerful Voltaic circles?

Tutor. They are those of the first order, where two solids, of different degrees of oxidability, are combined with a fluid capable of oxidating at least one of the solids. Thus gold, silver, and water, do not form an active voltaic circle, but it will become active if a little nitric acid, or any fluid decomposable by silver be mixed with the water. An active Voltaic circle is formed of zinc, silver, and water, because the zinc is oxidated by water. But a little nitric acid, added to the water, renders the combination still more active, as the acid acts upon the silver and the zinc.

The most powerful Voltaic combinations of the second order are, where two conductors of the second

class have different chemical actions on the conductors of the first class, at the same time that they act upon each other. Thus copper, silver, or lead, with a solution of an alkaline sulphuret* and diluted nitrous acid, form a very active Voltaic circle. Hence the following

* If equal quantities of sulphur and alkali be melted in a covered crucible, the mass obtained is called an alkaline sulphuret.

TABLES.

1. Table of Voltaic circles of the *first order*, composed of two perfect conductors, and one imperfect conductor.

Very Oxidable Substances.	*Less Oxidable Substances.*	*Oxidating Fluids.*
Zinc.....	With gold, charcoal, silver, copper, tin, iron, mercury	Solutions of nitric acid in water, of muriatic acid, and sulphuric acid, &c.
Iron.....	With gold, charcoal, silver, copper, tin	
Tin.....	With gold, silver, charcoal	Water holding in solution oxygen, atmospheric air, &c.
Lead.....	With gold, silver	
Copper.....	With gold, silver	Solution of nitrate of silver, and mercury, nitric acid, acetous acid.
Silver.....	With gold	Nitric acid.

II. Table of Voltaic circles of the *second order*, composed of two imperfect conductors, and one perfect conductor.

Perfect Conductors.	*Imperfect Conductors.*	*Imperfect Conductors.*
Charcoal.... Copper..... Silver..... Lead..... Tin..... Iron..... Zinc.....	Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three.	Solution of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals.

I will now show you another experiment, which is to be made with the assistance of the great battery. (Fig. 22.) A B (Plate II, Fig. 23) exhibits a glass tube, filled with distilled water, and having a cork at each end. A and B are two pieces of brass wire, which are brought to within an inch or two of one another in the tube, and the other ends are carried to the battery, *viz.* A to

what is called the positive end, and B to the negative end.

James. You have then positive and negative Voltaism, as well as electricity?

Tutor. Yes, and if the circuit be interrupted, the process will not go on. But if all things be as I have just described, you will see a constant stream of bubbles of gas proceed from the wire B, which will ascend to the upper part of the tube. This gas is found to be hydrogen, or inflammable air.

Charles. How is that ascertained?

Tutor. By bringing a candle close to the opening, when I take out the cork A, the gas will immediately inflame. The bubbles which proceed from the wire A are oxygen, or pure

air; they accumulate and stick about the sides of the tube.

James. How is this experiment explained?

Tutor. It is believed that the water is decomposed, or divided into hydrogen and oxygen: the hydrogen is separated from the water by the wire connected with the negative extremity, while the oxygen unites with and oxidates the wire connected with the positive end of the battery.

If I connect the positive end of the battery with the lower wire, and the negative with the upper, then the hydrogen proceeds from the upper wire, and the lower wire is oxidated.

If wires of gold or platina be used, which are not oxidable, then a stream

of gas issues from each, which may be collected, and will be found to be a mixture of hydrogen and oxygen.

Charles. Are there no means of collecting these fluids separately?

Tutor. Yes, instead of making use of the tube, let the extremities of the wires, which proceed from the battery, be immersed in water, at the distance of an inch from each other; then suspend over each a glass vessel, inverted, and full of water (Plate II, Fig. 24), and the different kinds of gas will be found in the two glasses.

It is known that hydrogen gas reduces the oxides of metals, that is, restores them to their metallic state. If, therefore, the tube (Fig. 23) be filled with a solution of

acetite of lead* in distilled water, and a communication is made with the battery, no gas is *perceived* to issue from the wire, which proceeds from the *negative* end of the battery, but, in a few minutes, beautiful metallic needles may be seen on the extremity of this wire.

James. Is this the lead separated from the fluid?

Tutor. It is; and you perceive it is in a perfect metallic state, and very brilliant. Let the operation proceed, and these needles will assume the form of fern, or some other vegetable substance.

Charles. Is not the operation of the battery very powerful?

Tutor. The spark from a Voltaic

* Acetite of lead is a solution of lead in acetous acid.

battery acts with wonderful activity upon all inflammable bodies, and experiments made in a dark room, upon gunpowder, charcoal, metallic wire, and metallic leaves, &c., may be rendered very amusing.

James. Has not the Galvanic battery been applied to the decomposition of certain substances that were formerly supposed to be simple bodies?

Tutor. Sir Humphrey Davy has, by means of a very powerful battery, been enabled to decompose the alkalies, many of the earths, sulphur, phosphorus, and charcoal: also the boracic, fluoric, and muriatic acids. His first experiments were on potash and soda, which, instead of being simple bodies, are found to consist of certain metallic substances and

oxygen.—See Dialogues on Chemistry.

Charles. Did he decompose these substances, by placing them within the circuit of the Voltaic fluid?

Tutor. He did, in a manner very similar to what you have seen in the experiments with the apparatus. (Plate II, Fig. 22.) The alkalies, &c., were placed on the glass, and the two wires brought from the positive and negative ends of the battery.

James. Did the wires partake of the like properties with the two ends of the battery.

Tutor. They did: one wire was positive, and the other negative. It was then found, after the action of the battery, that of the two substances, of which the alkali was com-

posed, one uniformly went to the positive, and the other to the negative wire.

Charles. You said the alkali was discovered to consist of a *metal* and *oxygen;* which of these united with the positive, and which with the negative wire?

Tutor. The oxygen was found at the end of the positive wire, and the metal at the negative end. Hence it was inferred, that oxygen was naturally negative, and therefore attracted by the positive wire.

James. Was the combination owing to the two substances being in opposite states?

Tutor. It was; and on this principle all the great discoveries of Sir Humphrey Davy are founded. He finds, from decisive experiments

frequently and most accurately repeated, that all bodies which chemically combine are naturally in opposite states.

Charles. But alkalies and acids chemically unite.

Tutor. True; and alkalies, containing much oxygen, are naturally *positive*, but acids are naturally *negative*. Hence their immediate union is accounted for on the common laws of electrical attraction. The two substances, being in opposite electrical states, attract one another, and the substance resulting from them is a neutral salt, possessing no electrical properties.

James. Can this experiment be reversed?

Tutor. It may; for if a neutral salt, as sulphat of soda, be brought

within the circuit of a Galvanic battery, it will be decomposed, and the acid, which is naturally negative, will be found at the positive wire, and the alkali at the negative wire.

Charles. Do chemical qualities, then, depend on electrical powers?

Tutor. They are seen, as far as experiments have gone, to coincide with certain electrical states of bodies in general. Acids, as we have observed, are uniformly negative; alkalies positive. Inflammable bodies are highly positive, and all are found to lose the peculiar properties and power of combination by a change of their electrical states.

CONVERSATION IV.

Miscellaneous Experiments,

TUTOR. The discoveries of Galvani were made principally with dead frogs; from his experiments, and many others that have been made since his time, it appears that the *nerves of animals* may be affected by smaller quantities of electricity than any other substances with which we are acquainted. Hence limbs of animals, properly prepared, have been

much employed for ascertaining the Voltaic electricity.

Charles. What is the method of preparation?

Tutor. I have been cautious in mentioning experiments on animals, lest they should lead you to trifle with their feelings: I must, however, to render the subject more complete, tell you what has been done.

The muscles, that is the flesh of a frog lately dead and skinned, may be brought into action by means of very small quantities of common electricity.

If the leg of a frog recently dead be *prepared*, that is, separated from the rest of the body, having a small portion of the spine attached to it, and so situated that a little electricity

may pass through it, the leg will be instantly affected with a kind of spasmodic contraction, sometimes so strong as to jump a considerable distance.

It is now known that similar effects may be produced in the limb thus *prepared*, by only making a communication between the nerves and the muscles by a conducting substance. Thus, in an animal recently dead, if a nerve be detached from the surrounding parts; and the coverings be removed from over the muscles, which depend on that nerve; and if a piece of metal, as a wire, touch the nerve with one extremity, and the muscle with the other, the limb will be convulsed.

Charles. Is it necessary that the

communication between the nerve and the muscle should be made with a conducting substance?

Tutor. Yes, it is: for if sealing-wax, glass, &c., be used, instead of metals, no motion will be produced.

If part of a nerve of a *prepared* limb be wrapped up in a slip of tin-foil, or be laid on a piece of zinc, and a piece of silver be laid with one end upon the muscle, and with the other on the tin or zinc, the motion of the limb will be very violent.

Here are two wine-glasses almost full of water, and so near to each other as barely not to touch. I put the *prepared* limb of the frog into one glass, and lay the nerve, which is wrapped up in tin-foil, over the edges of the two glasses, so that the tin may touch the water of the glass in

which the limb is not. If I now form a communication between the water in the two glasses, by means of silver, as a pair of tea-tongs; or put the fingers of one hand into the water of the glass that contains the leg, and hold a piece of silver in the other, so as to touch the coating of the nerves with it, the limb will be immediately excited, and sometimes, when the experiment is well made, the leg will even jump out of the glass.

James. It is very surprising that such kind of motions should be produced in dead animals.

Tutor. They may be excited also in living ones: if a live frog be placed on a plate of zinc, having a slip of tin-foil upon its back, and a communication be made between the zinc

and tin-foil by a piece of metal, as silver, the same kind of contractions will take place.

Charles. Can this experiment be made without injury to the animal?

Tutor. Yes, and so may the following:—I take a live flounder, and dry it with a cloth, and then put it in a pewter plate, or upon a large piece of tin-foil, and place a piece of silver on its back; I now make a communication between the metals with any conducting substance, and you see the contractions, and the fish's uneasiness. The fish may now be replaced in water.

I place this leech on a crown piece, and then, in its endeavour to move away, let it touch a piece of zinc with its mouth, and you will see it instantly recoil, as if in great

pain: the same thing may be done with a worm.

It is believed, that all animals, whether small or great, may be affected, in some such manner, by Voltaism, though in different degrees.

The limbs of people, while undergoing the operation of amputation, have been convulsed by the application of the instruments, an effect which is easily explained by Voltaism.

By the knowledge already obtained in this science, the following facts are readily explained.

Pure mercury retains its metallic splendour during a long time: but its amalgam with any other metal is soon tarnished or oxidated.

Ancient inscriptions engraved upon pure lead are preserved to this day, whereas some metals composed of

lead and tin, of no great antiquity, are very much corroded.

Works of metal, whose parts are soldered together by the interposition of other metals, soon oxidate about the parts where the different metals are joined. And there are persons who profess to find out seams in brass and copper vessels by the tongue, which the eye cannot discover; and they can, by this means, distinguish the base mixtures which abound in gold and silver trinkets.

When the copper sheeting of ships is fastened on by means of iron nails, those nails, but particularly the copper, are very quickly corroded about the place of contact.

A piece of zinc may be kept in water a long time, without scarcely oxidating at all; but the oxidation

takes place very soon if a piece of silver touch the zinc, while standing in the water.

If a cup made of zinc or tin be filled with water, and placed upon a silver waiter, and the tip of the tongue be applied to the water, it is found to be insipid; but if the waiter be held in the hand, which is well moistened with water, and the tongue applied, as before, an acid taste will be perceived.

Charles. Is that owing to the circuit being made complete by the wet hand?

Tutor. It is. Another experiment of a similar kind is the following: If a tin bason be filled with soap-suds, lime-water, or a strong ley, and then the bason be held in both hands, moistened with pure water, while the

tongue is applied to the fluid in the bason, an *acid* taste will be sensibly perceived, though the liquor is *alkaline*.

From this short account of Voltaism it may be inferred:—

(1.) That it appears to be only another mode of exciting electricity.

(2.) Voltaic electricity is produced by the chemical action of bodies upon each other,

(3.) The oxidation of metals appears to produce it in great quantities.

(4.) Voltaic electricity can be made to set inflammable substances on fire, to oxidate, and even inflame metals.

(5.) The nerves of animals appear to be most easily affected by it of any known substances.

(6.) Voltaic electricity is conducted by the same substances as common electricity.

(7.) When it is made to pass through an animal, it produces a sensation resembling the electrical shock.

(8.) The electricity produced by the torpedo and electrical eel is very similar to Voltaism.

GLOSSARY AND INDEX

TO THE

SIX VOLUMES.

A.

ABSORB, to drink in

Acceleration, a body moving faster and faster

Action and re-action, equal and contrary, vol. i, p. 116. Curious instance of, i, 120

Adhesion, a sticking together

Air, a fluid, the pressure of which is very great, iv, 1—3. Its pressure, experiments on, iv, 22—45. Its weight, how proved, iv, 46. Its elasticity, iv, 56—63. Its compression, iv, 69—78. Necessary to sound, iv, 92. Vehicle of heat and moisture, Appendix, iv

Air-gun, structure of, explained, iv, 87—89

Air-pump, described, iv, 9. Its structure explained, iv, 10—15. Experiments on, iv, 17 and 79

Alcohol, ardent spirit: equal parts of alcohol and water make spirits of wine

Alkaline, a saline taste

Anamorphoses, distorted images of bodies

Ancients, their mode of describing the constellations, ii, 14

Angle, what it is, i, 5. How explained, ib. Right, obtuse, acute, 6. How called, 7

Animals, all kinds of, affected by Galvanism, vi, 222

Aperture, a small hole

Aphelion, the greatest distance of a planet from the sun

Apogee, the sun's or moon's greatest distance from the earth

Aquafortis, of what composed, i, 13

Archimedes proposed to move the earth, i, 127. Some account of, iii, 147. His inventions, iii, 149

Arrow, to find the height to which it ascends, i, 68—70

Atmosphere, the effect of, v, 45, 46

Attraction, the tendency which some parts of matter have to unite with others

Attraction, capillary, what meant by, i, 30. Illustrated, i, 31

Attraction and Repulsion, electrical, vi, 9 and 43

———————, magnetic, v, 234, &c.

Aurora Borealis, vulgarly called the Northern lights. Its use in the Northern parts of the globe, ii, 189. Imitated, vi, 139. A curious one described, vi, 141

B.

Balance, hydrostatical, described, iii, 125

Balances, false, how detected, i, 142

Ball, why easily rolled, i, 76. Scioptric, its effect, v, 71

Barometer explained, iv, 50 and 201—210. Its construction, iv, 190. Its use, ib. Standard altitude of, iv, 194. Variation of, ib. To measure altitudes with, iv, 201

Battery, electrical, described, vi, 89. Experiments on, vi, 92

Beccaria, his observation, vi, 135

Bellows, hydrostatical, iii, 61—70

Birds, how they support themselves in the air, i, 102

Bissextile, the meaning of the word, ii, 139

Bodies, heavenly, why move in a curved path, i, 114. Elastic and non-elastic, illustrative of the third law of motion. Weight of, diminished as the distance from the centre of the earth is increased, i, 57. Falling, the law of their velocity, i, 71. How to insulate, vi, 31. Sonorous, elastic, iv, 100. Heavenly, the latitude of, ii, 46

Body, moving one, what compels it to stop, i, 98

Bodies, their vis inertiæ, i, 106

Boyle, Mr., first saw the electrical light, vi, 6

Bride's (St.), church, damaged by lightning, vi, 127

Bucket, how suspended on the edge of a table, i, 87
Buffon, M., his experiments, v, 106
Bullets, leaden, how made to cohere, i, 22

C.

Camera obscura, v, 218
Cannon, the sound of, iv, 99
Capillary attraction, fluids attracted above their level by tubes as small as a hair
Cardinal points, how distinguished, ii, 14
Cavallo, Mr., his electrical experiments, vi, 125
Catoptrics, the science of reflected light
Centre of gravity, the point of a body, on which, when suspended, it will rest. Between the earth and sun, ii, 98. How applicable to the common actions of life, i, 84
Centrifugal force is the tendency which a body has to fly off in a straight line
Centripetal force is the tendency which a body has to another about which it revolves
Chatterton, his lines on the solar system, ii, 57
Circles, Galvanic, what, vi, 201. First order, ib. Second order, ib. The most powerful, vi, 203
Clepsydra, principle of, explained, iii, 86
Climates, how improved, Appendix, iv
Clocks and Dials, why not agree in the measure of time, ii, 129—136

Cohesion, attraction of, i, 18. How defined, i, 20. Instances, i, 21. Its force, i, 23. How overcome, ib. Instances of, i, 28

Coining, apparatus for, referred to, i, 198

Colours, the cause of, v, 89

Comets, in what respects they resemble planets, ii, 230. The heat of one calculated, ii, 232

Compression, the act of squeezing together

Condensation, the act of bringing the parts of matter together

Conductors, electrical, what meant by, vi, 15. Table of, vi, 20. Galvanic, vi, 200. Perfect and imperfect, ib. 201

Cone, double, why it rolls up a plane, i, 88

Contact, touching

Converge, drawing towards a point

Cookery, some operations of, how accounted for, i, 24

Crane, the principles of a, i, 161. One invented by Mr. White, i, 164. Distiller's described, iii, 195

Cupping, the operation of, explained, iv, 65—67

Cups, hemispherical, experiments on, iv, 42

Cylinder, how made to roll up a hill, i, 86

D.

Dancers, rope or wire, how they balance themselves, i, 83

Day, astronomical, when begins, ii, 41. The difference between the *solar and sidereal*, ii, 127

Day and Night, how explained, ii, 84.

Days and Nights, why of different lengths, ii, 92. To whom always equal, ii, 107

Deception, optical, ii, 3. In feeling, ib.

Deceptions, on the public, by short weights, how detected, i, 144. Occasioned by swift motions, ii, 78, 79. Optical, v, 39—43, and 133, &c.

Delaval, Mr., his experiments, v, 97

Density, compactness. Constitutes specific gravity, iii, 116

Diagonal, the lines which join the opposite corners of a square or other right-lined figure

Digester, used for making soups

Direction, line of, how defined, i, 74. Must be within the base of a body that stands secure, i, 75

Distance, measured by sound, iv, 104

Diver's Bell described, iii, 201—203. How used, iii, 204—207. Accidents with, iii, 208—210. Smeaton's improvements on, iii, 210. Walker's improvements on, iii, 212. Anecdote of, iii, 213

Diverge, to spread out

Drowning, the danger of, to inexperienced persons, iii, 158

E.

Earth, centre of, why bodies move to it, i, 51. Why not apparently moved, i, 53. Its shape, i, 58. Its diurnal motion, ii, 67, 70—82. The velocity of its motion, ii, 80. When its motion is quickest, ii, 135. Its annual motion, ii, 82, and 93—99. Its rotation, the most uniform motion in nature, ii, 127. A satellite to the moon, ii, 153. No arguments against its motion because not apparent, ii, 74. Its magnitude, ii, 80, 81. Its globular figure, ii, 59. How proved, ii, 60, 65. Its poles, what, ii, 66. Its axis, ii, 67

Echo, the nature of, explained, iv, 188—161. Curious ones noticed, iv, 130. Applied to the measuring of distances, iv, 131

Eclipse, an occultation of the sun or moon

Eclipses, the cause of, explained, ii, 157, 167. Annular, ii, 164. Total, of the sun, very rare, ii, 165. Account of one seen in Portugal, ib. Supposed to be omens of calamity, ii, 167

Ecliptic, the earth's annual path round the heavens. How described, ii, 26. How to trace the, ii, 28—31

Effluvia, fine particles that fly off from various bodies

Eggs, discoloration of silver with eating, vi, 202. How explained, ib.

Elasticity, the quality in some bodies, by which they

recover their former positions after being bent. What meant by, i, 37

Electric, what meant by, vi, 5. Light, by whom first seen, vi, 6

Electricity, history of, vi, 1. Attraction, electrical, when first noticed, vi, 4. Atmospheric, vi, 134. The two kinds, vi, 45. Medical, vi, 152. Animal, vi, 161

Electrometer, Lane's, vi, 81. Quadrant, the use of, vi, 86. Another kind, vi, 119

Eolian Harp, structure of, explained, iv, 136—139

Ephemeris, an almanac. White's, explained, ii, 33

Equator, how described, ii, 27 and 68

Equinoctial, what meant by, ii, 68

"*Evenings at Home*," referred to, a work of great merit, i, 3

Eye, the parts of which composed, v, 140

F.

Feathers, electrified, their appearance, vi, 61

Fire Engines described and the principle of them explained, iii, 229

Fish, how they swim, iv, 4. Air-vessel of, the uses, iv, 7. Electrical, vi, 60

Flannel, a conductor of sound, iv, 96

Flea, circulation of the blood of a, i, 19

Flood-gates, why made very thick, iii, 88

Fluids and Solids, how distinguished, iii, 34—36. Particles of, exceedingly small, iii, 7. Incapable of compression, iii, 11, 12

Fluids press equally in all directions, iii, 21. Incompressible, iii, 25. Air, compression of, ib. Weight and pressure of, experiments on, iii, 28—32. Lateral pressure of, iii, 40—47. Difference between the weight and pressure of, iii, 81. Motion of, iii, 82—105. Experiments on the light and heavy, iii, 167—171. Specific gravity of, differs according to the degrees of heat and cold, iii, 175

Force, centrifugal, what meant by, i, 106

Fountain, artificial, iv, 73

Fountains, the principle of, explained, iii, 98

Franklin, Dr., his experiments, vi, 122. Discovers that lightning and electricity are the same, vi, 124

Friction, rubbing. Must be allowed for in Mechanics, i, 171

Frogs, experiments on, vi, 216—221

Fulcrum, the prop or centre on which a lever turns. What meant by, i, 130, 131

G.

Galvani, Dr., his discoveries, vi, 181, 182. Experiments on frogs, ib. and 216

Galvanic batteries, how formed, vi, 192—195. Shock, vi, 193—196

Galvanism, what it is, vi, 181. From what it derived its name, ib. And electricity the same, vi, 185. Made apparent to the senses, vi, 187. Positive and negative, vi, 207. Summary of, vi, 225

Garden engines, described, iii, 230

Gas, a kind of air. Hydrogen, how procured, vi, 207. How collected, ib.

Gauge, a measure

Geocentric place of a planet, what meant by, ii, 212. Longitude, ii, 213

Globe, the greater part of its surface water, iv, 146. A representation of the earth, ii, 65

Glue, for what used, i, 32

Gravity, the tendency which bodies have to the centre of the earth. Centre of, what meant by, i, 73. How found, i, 74. Acts upon all bodies, i, 41. The law of, i, 42 and 54. Illustrated, vi, 42—45, and 54—57

Gravitation, attraction of, defined, i, 38. Instances of, i, 38. By this force bodies tend to the centre of the earth, i, 40

Gregory, Pope, rectifies the Julian year, ii, 141

Guinea, specific gravity of, iii, 127

Gunpowder, how fired, vi, 197

Gymnotus, described, vi, 164

H.

Hammer, philosophical, iv, 21

Hampstead, the fine prospect from, v, 156

Harvest-moon, explained, ii, 179—190. Cause of, ii, 181

Heat expands all bodies, i, 25. The cause of great, ii, 108. Of a day, on what depends, Appendix, iv

Height of any place, how found, i, 64

Heliocentric longitude, ii, 211

Herschel, the planet, when discovered, ii, 226. Its magnitude, distance, &c., ii, 127—229

Hiero's crown, cheat respecting, how detected, iii, 151—154

Hogshead, how burst, iii, 68

Hop-waggons, dangerous to meet in an inclining road, i, 81

Horizon, the boundary where the sky seems to touch the surface of the earth or sea. Sensible and rational, ii, 84. To which we refer the rising and setting of the sun, ii, 85

Humidity increases the transparency of the atmosphere, Appendix, iv

Hydraulics, hydrostatic principles applied to mills, engines, pumps, &c.

Hydrometer, an instrument to measure the strength

of spirits. Described, iii, 171—176. To what applied, iii, 177

Hydrostatics, the origin of the term, iii, 2. The objects of, ib.

Hydrostatical paradox, explained, iii, 48—60

Hydrostatical bellows, described and explained, iii, 61—70. Press, iii, 70 and 233—235. Fluids, pressure of, in proportion to the perpendicular heights, iii, 62

Hygrometer, an instrument by which the moisture of the air is measured. Its construction and use, iv, 235. Different kinds of, iv, 235—241

I and J.

Jack-a-lanthorn, vi, 143

Immerse, to plunge in

Impel, to drive on

Incidence, line of, iv, 123

Incompressible, not capable of being pressed into a smaller compass

Inertia of matter, its tendency to continue in the state in which it is

Ingenhouz, Dr., referred to, i, 33. His character, i, 34

Interstices, the hollow spaces between the particles of matter

Iron, oxide of, vi, 189

Jupiter, the planet; its magnitude; distance from the sun; the velocity of its motion, ii, 214. The length of its days and nights, ii, 216. Satellites, ii, 217

Julius Cæsar, the part he took in reforming the year, ii, 138

L.

Lateral, sidewise

Latitude of the planets, their distance from the ecliptic. Parallels of, ii, 105

Lead, eleven times heavier than water, iii, 46. Oxide of, vi, 187. Acetite of, vi, 210

Leaf, gold, silver, &c., how burnt, vi, 197, 198

Leaks, in banks, how secured, iii, 90

Leap-year, what meant by, ii, 137. Rule for knowing, ii, 140

Lenses, different kinds described, v, 49

Levels, construction of, iii, 17. Use of, iii, 17—20

Lever, a bar, crow, &c. For what used, i, 132. Why called a mechanical power, i, 133. Of the *first* kind, what instruments referred to, i, 145. How to estimate its power, i, 146. Of the *second* kind, what instruments referred to, i, 147. Of the *third* kind, what instruments referred to, i, 151, 152

Levers, how many kinds, i, 133. Their properties illustrated, i, 134—140

Light, its great velocity, how discovered, ii, 218, and v, 6. Of what composed, v, 2. Sun, subject to apparent diminution, v, 4. The source of light to the planetary worlds, ib. Moves in straight lines, v, 11, 12. Ray of, what meant by, v, 13. Reflected and refracted, v, 13—30. Its great advantages, v, 80. A compounded body, v, 83. Galvanic, how perceived, vi, 190—192

Lines, right, what meant by, i, 5

London, how supplied with water. Bridge, waterworks at, iii, 101 and 228

Long days, the reason of, ii, 105

M.

Machine, electrical, vi, 21. The most powerful, vi, 33

Magnet, described, v, 226. Its uses, v, 227. Directive property, ib. Artificial, v, 229. Properties of, v, 231

Magnets, how to make, v, 246

Magnetic attraction and repulsion, v, 235

Marbles, reason why they roll to greater or less distances, i, 93

Mariner's compass, described, v, 242. Variation of, v, 252

Mars, the planet, its distance from the sun; its velocity; its magnitude, &c., ii, 207—212

Matter, every substance with which we are acquainted. How defined, i, 10. Definition illustrated, i, 11. Capable of infinite division, i, 12. Remarkable instances of the minute division of, i, 16—17

Mechanical Powers, how many, and what they are, i, 126.

Mechanics, importance of, i, 128. Power gained by them, ib.

Mercury, the planet, its situation, ii, 191, and Venus, why called inferior planets, ii, 191. Rarely seen, ii, 193. Its distance from the sun; its velocity; its size, &c., ii, 194—197

Metals, some more sonorous than others, iv, 100

Meteoric Stones, how accounted for, Appendix, iv

Microscope, its principle explained, v, 198. Single, v, 200. How made, v, 204. Compound, v, 206. Solar, v, 211

Mirrors, the different kinds, v, 99

Momentum, the moving force of a body. What meant by, i, 46. Illustrated, i, 47—50, and 121

Money, counterfeit, wrong to pass it, iii, 160

Month, what meant by, ii, 145. Difference between the periodical and synodical, ii, 146

Moon, to what laws subject, i, 59. Its declination, ii, 41. Its southing, ib. Its distance from the earth, ii, 86. Probably inhabited, ii, 154. Eclipses of, ii, 158

—— *and earth*, motions of, explained, ii, 147, 148.

Shines with borrowed light, ii, 148. The length of her diameter, ii, 149. Phases of, explained, ii, 150. Her rotation described, ii, 152. Length of her day, ib. Length of her year, ii, 153

Motion, centre of, what it is, i, 124. Laws of, i, 89. Must be committed to memory, i, 103, 104; the first illustrated, i, 90—98; the second illustrated, i, 98; the third illustrated, i, 99—102

Motions, circular, exist in nature, i, 105

Muschenbroeck, M., describes the electric shock, vi, 71

Musical instruments depend on the air for action, iv, 135

N.

Nadir, the point under our feet

Nautical Almanac, its use, ii, 31

Needle of the mariner's compass. Dipping, v, 254—256

Nerves and Muscles, how conductors of the Galvanic fluid, v, 183

New Style, when adopted, ii, 142

Newton, sir Isaac, his experiments on electricity, vi, 6

Ninkler, M., his description of the electrical shock, vi, 71

O.

Objects, by what means visible, v, 31. The image of, how painted on the eye, v, 154
Oblate, of the shape of an orange
Opaque, dark
Orbit, the path of a planet round the sun, or of a moon round its primary
Oxidation, what meant by the term, vi, 186—189
Oxide, the calx of a metal. What meant by the term, vi, 189

P.

Paley, Dr., his Natural Theology referred to, v, 156
Papin's digester described, i, 27, and iv, 185. Its uses, ib. One burst, iv, 188
Parker, Mr., his large burning-glass, v, 54
Percussion, a stroke. What meant by, 116, 117
Phenomenon, an appearance in nature
Phial, Leyden, where discovered, vi, 69
Philosophy, what it is, i, 2. Natural and experimental, the introduction to, not difficult, i, 3. Natural, the uses to which it is applied, i, 97
Philosophical Transactions, referred to, vi, 137
Pisa, tower of, leans out of the perpendicular, i, 78

Plane, inclined, explained, i, 174. Examples respecting the, i, 177—181. What instruments referable to, i, 181

Planets, their number and names, ii, 53. Characters of, ii, 38. Latitude of, ii, 45. The order of their motions, ii, 53. How to find their distances, ii, 204—206

Pneumatics, what treated of under, iv, 1

Points, cardinal, ii, 14

Pole-star, its use, ii, 15

Poles, apparently stationary, ii, 90. At the, only one day and one night in the year, ii, 121

Press, hydrostatical, iii, 70

Priestley, Dr., his History of Electricity referred to, vi, 8

Price, Dr., referred to, i, 61

Prism, the effect of, v, 169

Puddling, what meant by the term, iii, 90, 91

Pulley, how explained, i, 166. The single gives no advantage, i, 167. The moveable, i, 169

Pump, principle of, iii, 215—224

Pump, forcing, described, iii, 225

Pyrometer, its construction and use, iv, 230

R.

Radiant-points, from whence rays of light flow in all directions

Rainbow, the cause explained, v, 167. Artificial, v, 176. Curious ones described, v, 177

Rain, cause of, explained, Appendix, iv

Rain-gauge, its construction, iv, 243. How it is used, iv, 244

Rain, an electrical phenomenon, vi, 148

Rays, pencil of, what meant by, v, 47. Parallel, definition of, ib.

Reflection, rebounding back. Its powers in apparently multiplying objects, ii, 7. Line of, explained, iv, 121

Refraction, inclining or bending out of its course. Its power in apparently multiplying objects, ii, 10

Repulsion, driving away. What meant by, i, 34. Instances of, i, 35—37

Residuum, electrical, what meant by, vi, 80

Retrograde motion, by which the heavenly bodies appear to go backwards

Reverberate, to beat back

River, New, how it supplies London with water, iii, 100. Reservoirs belonging to, iii, 101, 102

Rivers, banks of, must be very thick, iii, 89

Roundabouts, the principle of, i, 124

S.

Saliva, decomposed by Galvanism, vi, 186
Salt, whatever has a sharp taste, and is soluble in water
Salt water, heavier than fresh, consequence of, to a loaded vessel, iii, 179
Satellites, moons
Saturn, the planet, how known, ii, 220. Its magnitude; distance from the sun; velocity of its motions, ii, 221. Its satellites and rings, ii, 222—224. The length of its day and night, ii, 225.
Screw, an inclined plane wrapt round a cylinder. Its principle explained, i, 183. Of what composed, i, 189. Examples of, i, 190. Used by paper makers, i, 196. Its power estimated, i, 197
Season, the hottest, ii, 114
Seasons, variety of, on what depends, ii, 100 and 107. Different, how accounted for, ii, 93, and 100—123. How produced, ii, 114
Ship, damaged by lightning, vi, 138
Silurus electricus described, vi, 167
Silver, experiment with, vi, 183
Slaves, how they get at their master's rum, iii, 169
Smoke, the reason of its ascent, iv, 82
Smoke Jack, its principle, iv, 143
Solar System, described, ii, 43—58
Solder, for what used, i, 32

Sound, conductors of, iv, 94—26. How far may be heard, iv, 102. How fast it travels, iv, 105. Velocity of, applied to practical purposes, iv, 107—110

Spark, electrical, its nature, vi, 103. Galvanic, its power, vi, 210

Specific gravity, what meant by, iii, 33. Of bodies explained and illustrated, iii, 106—165. How to find, iii, 110

Spectacles, their construction, uses, and different kinds, v, 159—162

Spirit, rectified, what meant by, iii, 175

Springs, intermitting, explained, iii, 197

St. Paul's, whispering gallery of, principle explained, iv, 132

Stars, how to find the names of, ii, 18—24. Why marked on the globe with Greek characters, ii, 24. Fixed, their apparent motion, ii, 89. Why not seen in the day, ii, 92. Fixed, their number, ii, 1—4. May be distinguished, ii, 12. Fixed, their immense distance, ii, 129. Fixed, description of, ii, 240—246. Their uses, ii, 247. Falling, what they are, vi, 134

Steam-engine, its use, iv, 156. When invented, iv, 158. Its structure, iv, 163. The application, iv, 177, 178. That of Messrs. Whitbread described, iv, 180. Its power calculated, iv, 181. Accidents occasioned by, iv, 183

Steelyard, a sort of lever, i, 138. Its advantages over a pair of scales, i, 240

Stones, meteoric, Appendix, iv

Storms, by what occasioned, iv, 152

Suction, no such principle in nature, iv, 32—39

Sulphuret, alkaline, what, vi, 204

Summers, two in a year, in some places, ii, 119

Sun and clocks, seldom together, ii, 44

Sun, declination of, ii, 40. Longitude of, ii, 46. Has not latitude, ii, 46. Its magnitude, ii, 50. Why it appears so small, ib. Its distance from the earth, ii, 51. Annual motion of, how observed, ii, 95. Reasons for, ii, 26. Nearer to the earth in winter than in summer, ii, 111. A description of, ii, 237—239

Swimming, theory of, iii, 180. How to be attained, iii, 181. Less natural to man than to other land animals, iii, 182

Syphon, the structure of, explained, iii, 187. Its principle, iii, 189

Syringe, its structure explained, iv, 25. Condensing one described, iv, 75

T.

Tables, Galvanic, vi, 205, 206

Tangent, a straight line touching the circumference of a circle in one point

Tangible, capable of being felt or handled
Tantalus's cup, iii, 192
Taste, a disagreeable one, excited by the union of metals placed on and under the tongue, vi, 185. How accounted for, vi, 187
Telescope, refracting, explained, v, 178. Night, v, 197 Reflecting, explained, v, 191. Dr. Herschel's, v, 197
Temperatures of the air, to what limited, Appendix, iv
Terms, technical, derived from the Greek language, iii, 1
Thermometer, its construction and uses, iv, 211—219. Its scale, iv, 218. Wedgewood's, iv, 223. Reaumur's scale compared with Fahrenheit's, iv, 228. Heat, scale of, iv, 226
Thunder, how produced, iv, 98
Tides, the causes of, explained. ii, 168—178. Two every 25 hours, ii, 178. Different in different places, ii, 175. When the highest happen, ii, 178.
Time, equal and apparent, how distinguished, ii, 124—126. On what the difference depends, ii, 126. Equation of, ii, 43 and 124—136. Division of, ii, 144
Time and space, clear ideas of, necessary to be formed, i, 126
Torpedo described, vi, 161
Torricellian experiment, iv, 22
Transferrer, an instrument used in Pneumatics
Transit of Venus, her passage over the sun's face
Trembling-eel noticed, vi, 168
Triangle, what meant by, i, 9. Any two sides of, greater than the third, i, 113

Tropics, circles parallel to the equator
Trumpet, speaking, described, iv, 111—117. When first used, iv, 114
Trumpets for deaf persons, iv, 116
Tube, a pipe
Twilight, the degree of light experienced between sun-setting or rising and dark night

U and V.

Undulation, swinging or vibrating
Vacuum, a place void of air
Valve, a sort of trap door
Valves, what meant by, iii, 216
Vegetables, how blanched, v, 93
Velocity, a term applied to motion. Accelerating, what meant by, i, 62
Venus, the planet, its distance from the sun; the velocity of its motion; its magnitude, ii, 198—202. Why an evening and why a morning star, ii, 202. Transit of, what meant by, ii, 203
Vernier, its construction and use, iv, 195
Vertex, the top of any thing
Vibration, the swinging motion of a pendulum
Vision, the manner of, v, 148
Volatile, any light substance, that easily evaporates
Voltaic batteries, vi, 192—195. Shock, vi, 193—196
Voltaism, vi, 192, &c.

W.

Wall, leaning one, at Bridgenorth, i, 79

Water, pure rain, the standard to compare other bodies with, iii, 112. Weighs the same everywhere, iii, 113. Always deeper than it appears to be, iii, 184; and v, 37. How raised from deep wells, iii, 230—233. Formed of two gases, vi, 186. Decomposed, vi, 208

Water-spouts, their cause, vi, 144. How dispersed, vi, 145

Weather, rules for judging of, iv, 248—252. Why very bright before rain, Appendix, iv

Wedge, a triangular piece of wood or metal, to cleave stone, &c. Its principle explained, i, 182. Its advantages in cleaving wood, i, 183. What instruments referred to, i, 185

Well, how to find the depth of one, i, 65

Wheel and axis, described, i, 157. For what purposes used, ib. Its power estimated, i, 159. How increased, i, 160. Explained on the principle of the lever, i, 165

White, Mr. James, his invention of a crane, i, 164. His patent pulley, i, 172

Wind, what it is, iv, 140. The cause of, iv, 141. Experiment on, iv, 142 and 149. Definition of, iv, 144. Its direction denominated, ib. The cause of

its variableness in England, iv, 150. How to find its velocity, iv, 152. Table of, iv, 155

Winds, how many kinds, and why so named, iv, 144

Winter, why colder than the summer, ii, 112

Y.

Year, its length, how measured, ii, 138. Gregorian, what meant by, ii, 141. The beginning of, changed from the 25th of March to the 1st of January, ii, 143

Z.

Zenith, that point of the heavens over one's head

Zinc, experiment with, vi, 183

Zodiac, a belt in the heavens, sixteen degrees broad, through which the ecliptic runs. Signs of, ii, 35. Dr. Watts's lines on, ii, 38

THE END.

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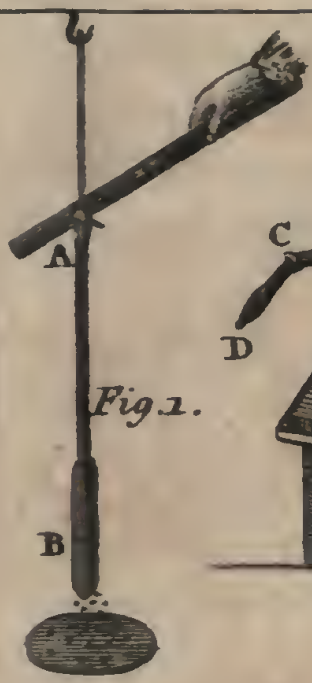

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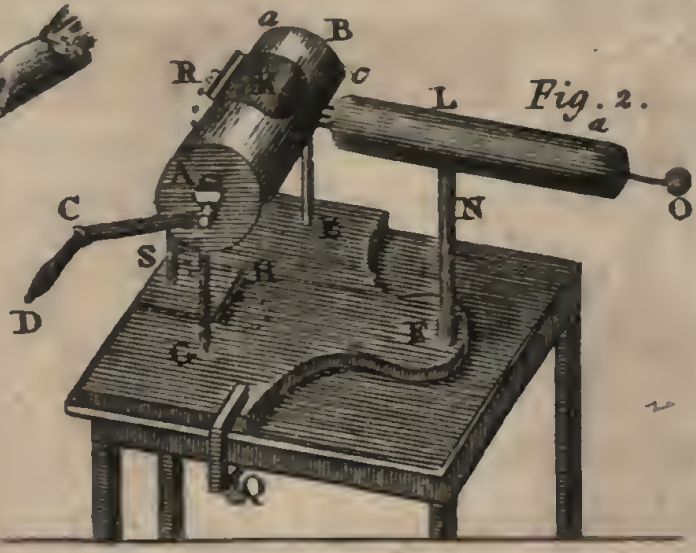

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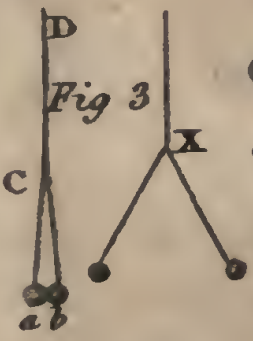

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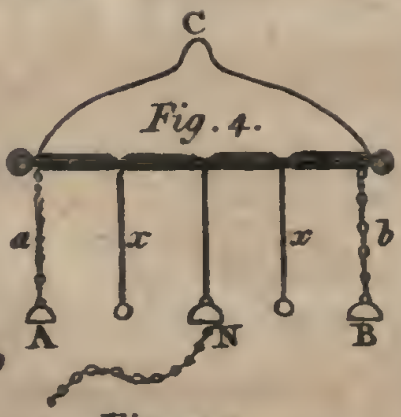

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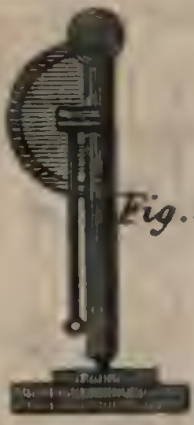

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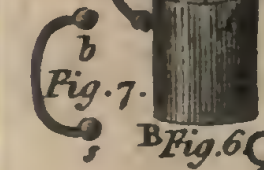

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B Fig.6

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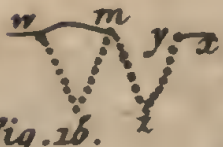

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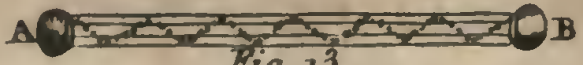

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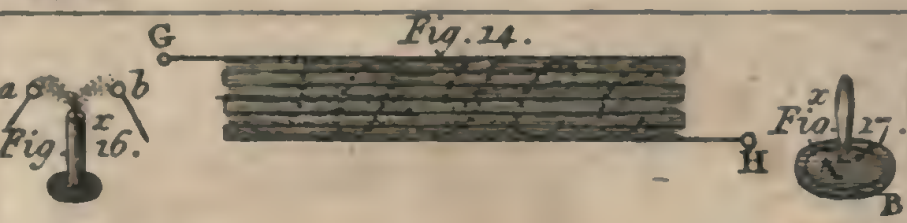

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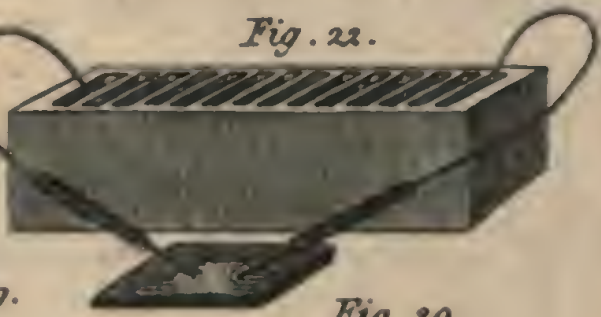

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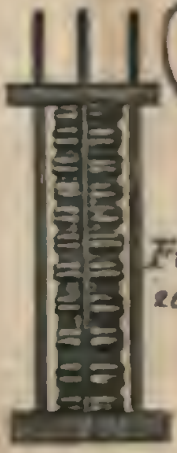

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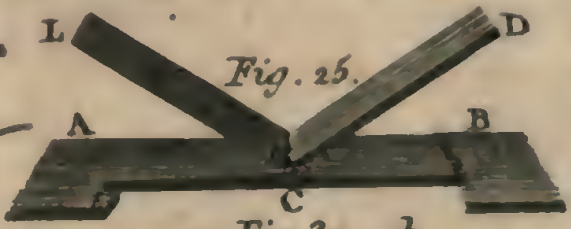

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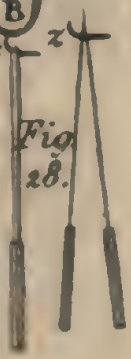

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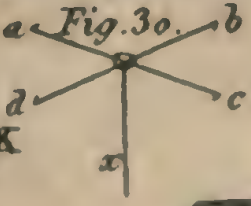

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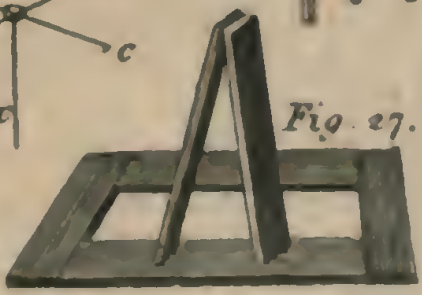

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